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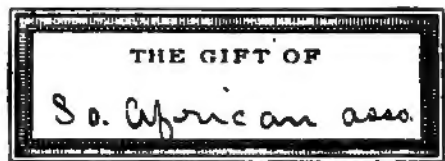
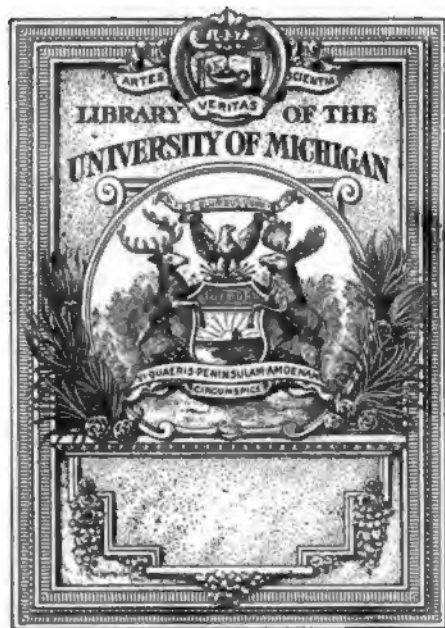
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South African  
Association for the  
Advancement  
of Science.

Johannesburg, 1904.





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REPORT  
OF THE  
SOUTH AFRICAN *Journal of Science* ~~ASSOCIATION~~

~~FOR THE~~  
ADVANCEMENT OF SCIENCE

SECOND MEETING

HELD AT

JOHANNESBURG

APRIL 1904

PUBLISHED BY THE ASSOCIATION

1904



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# PRESIDENT'S ADDRESS.





## ADDRESS

BY

SIR CHARLES METCALFE, BART.,

PRESIDENT.

I have to thank you for the honour done me by electing me as your President, an honour which I feel all the more deeply because I am painfully aware of how little I have been able to do personally by scientific record or research. I can at least assure the members of our Association, whom we welcome here to-night, that I shall always do what I can for the purpose of this Association for the Advancement of Science.

Our past President, Sir David Gill, in his inaugural address at Cape Town last year on the occasion of the first annual meeting of this Association, dealt with it and its history since its inception.

The number of ordinary members then on the roll was 702, and the number of associates 32; the number of ordinary members to-day is 913, and that of associates 124.

A copy of the report of our last year's meeting has, I trust, reached every one of our members. We have to express our regret that it has come to hand so late, but the work involved in its compilation was arduous in the extreme, and our thanks are due to the Rev. Mr. Flint, who has spent a long period of valuable time on the work. We have to express the thanks of the Association to the Government of the Cape Colony, who generously undertook the cost of the whole printing the reports and papers of last year's meeting, and I think you will agree with me that the production is a handsome as well as a valuable one.

The fifty-six papers to be read before this meeting of our Association, their subjects and the names of their authors, make it certain that the second volume of our proceedings will be at least of equal interest to the first, and will prove a very valuable addition to any library.

We very heartily thank His Excellency Lord Milner for the valuable and consistent assistance he has given to this Association, and we congratulate ourselves on the kindly interest he has always taken in our proceedings.

Our thanks are also due to His Excellency Sir Arthur Lawley for kindly inviting the members of this Association to

a Garden Party at Government House, Pretoria, on Thursday next.

The official Souvenir Programme shows not only that a busy week is before you with a very full and promising list of papers, many of which deal with questions of vital importance to this community, but also that another purpose of this Association, namely, the promotion of social intercourse of all those interested in science, has been amply provided for. For their kind help and hospitality, now proffered to us, we beg to thank the Mayor and Town Council of Johannesburg, the Transvaal Chamber of Mines, Sir George and Lady Farrar, Mr. and Mrs. Reunert, the members of the Stock Exchange, the Chamber of Commerce, the Chamber of Trade, the Pretoria Committee, the managements respectively of the Robinson, the Robinson Deep, the Ferreira and Ferreira Deep, and the Premier Mine, the South African Explosives Company, and the local scientific societies.

The arrangements for such a meeting as this involved a great deal of arduous work, and we tender our best thanks to Mr. Reunert, to whom the starting of this Association was mainly due, for the unremitting labour, the time, and the thought that he has devoted to it, and also to his able coadjutors.

Next year we hope, in July, 1905, to welcome the visit of the British Association to this country, a visit that the members of that Association, I am assured, look forward to with pleasure, and that we all anticipate will be productive of great good. The many complicated problems of this young country, of a nation in the course of making, cannot fail to interest men whose life is spent in investigation and research, whilst personal intercourse with great intellects must exercise a stimulating influence on ourselves. It is a liberal education in itself to know, for instance, a man like Lord Kelvin, who, in spite of the fact that he will be eighty-one years of age next year, hopes then to visit us. All his life has been devoted to the advancement of the intellectual and material progress of humanity. He is equally well known and honoured for his contributions to applied science as to purely scientific research. Steam and heat engines, electricity, marine telegraphy, and ocean navigation have all benefited to a very large extent by the inventions and researches which have occupied his long and useful life. His influence on his students and others engaged in scientific work has been all for good, a wonderful record of a great man's life work, and yet the traits of his character which most impress anyone who has the privilege of knowing him are his kindliness, his love of truth, and his humility—an object lesson to all those who tread the path of science.

During the past year progress has been made with the magnetic survey of South Africa. Dr. Beattie has kindly furnished me with the following data concerning it. The work

at each station consisted in determining the latitude and the longitude of the place of observation, the magnetic declination, the horizontal intensity, and the dip. These observations have been made at 362 stations, distributed as follows:—

Cape Colony	...	...	...	...	160
Transvaal	...	...	...	...	90
Orange River Colony	...	...	...	...	47
Natal	...	...	...	...	37
Rhodesia	...	...	...	...	28

The following observers have taken part in the work:—

	Stations observed.
Professor Beattie	... .. 359
Professor Morrison	... .. 100
Mr. Lowinger	... .. 48
Mr. Hough	... .. 12

The data obtained are at present being reduced; the first reduction is about two-thirds finished, and it is hoped it will be completed about the end of May. The second reduction will probably require about six months.

The total money grant for the purpose of the Survey, £2,465 10s., was constituted as follows:—

Cape Colony	...	...	...	...	...	£788	0	0
Transvaal	...	...	...	...	...	577	10	0
Orange River Colony	...	...	...	...	...	250	0	0
Natal	...	...	...	...	...	200	0	0
Rhodesia	...	...	...	...	...	200	0	0
Royal Society, London	...	...	...	...	...	300	0	0
Professors Beattie and Morrison	...	...	...	...	...	150	0	0

The geological survey of the Cape Colony has made steady progress during the past year. Two special points of interest were:—

1. The examination of a peculiar group of volcanic necks in Sutherland; agglomerates with several features in common with the Kimberley breccias were found associated with melilite basalt, a type of rock that had only been found in South Africa previously in a neck in Uitenhage beds.
2. The discovery of a glaciated boulder pavement in the Dwyka Conglomerate of Ceres, with a surface in this conglomerate over which a sheet of ice travelled—the first case of a boulder pavement in rocks older than the Pleistocene glacial deposits of Europe and America.

The Marine investigations carried out by the Cape Government during 1903 have brought to light many new and interesting specimens of marine life.

The past year has been notable, from a scientific point of view, for the discoveries due to the research on Radium, carried out by many of the greatest scientists of the day, especially by

Professor Rutherford, Sir William Ramsay, Mr. Soddy, Professor Becquerel, Sir William Crookes, Professor Dewar, and last, but not least, by M. and Mme. Curie, to whom the "Sir Humphrey Davy" medal of the Royal Society was awarded for their important contributions to the knowledge of its extraordinary properties. Some idea of the laborious and patient investigations which M. and Mme. Curie have carried out may be gathered from the fact that after two years of continuous work they have succeeded in obtaining about one gramme of Radium chloride after treating some eight tons of uranium residues. This gives us a good illustration of a great saying that "science is slow." Professor Rutherford has investigated the gaseous radiations emitted by radium, which he has called the alpha, beta, and gamma rays. Professor Becquerel has determined the mass and the velocity of the beta rays, which he found to be negatively charged particles. Sir William Crookes, by means of an ingenious instrument called the Spintariscope, which he has invented, has been able to observe the scintillations produced by the impact of alpha ray particles, and Professor Dewar has found that radium at the temperature of liquid hydrogen, that is to say at a temperature only a few degrees above what is called absolute zero, is just as active as at ordinary temperatures.

The physiological action of radium rays is now being investigated, and research is being made as to its possible application in cases of cancer and other dangerous growths.

Good progress, I am glad to say, has been made in the standardisation of all classes of engineering work, with a view to economy of manufacture, which is so essential in these days of acute competition.

The enterprising firms of Messrs. Siemens and Halske and the Allgemeine Electricitäts Gesellschaft may be congratulated on the records that have been made in high speed electric traction on the Marienfelde-Zossen line in Germany, where a maximum speed of 130 miles an hour was attained with safety. During the past year new and more satisfactory single-phase series wound commutator motors have been brought out in Europe and America, which will probably have a most important influence on the electrification of railways.

Electric furnaces have been employed for some years for the formation of calcium carbide and carborundum; during the last two years their use has been extended to the making of tool steel, and more recently even to the making of ordinary steel, where water power is very cheap and coke is expensive, as at Livet, in France, where Mr. Keller is at work. This, though at present in a more or less experimental stage, has excited a considerable amount of attention, and I am informed by one of the partners, Mr. Lelu, that a deputation from Canada was going to visit the works this month.

In Metallography progress has continued to be made in

our knowledge of the internal structure of metals by the aid of microscopical research. The old methods of analysis and of mechanical tests gave us indeed rough ideas of their limit of elasticity and of their ultimate breaking strength, but they told us nothing of the changes in their structure that are caused by the treatment undergone by the metal from pressure, undue strain, or different temperatures. By the microscopical examination of polished sections we are now finding out how the internal structure of metals and their alloys is arranged and re-arranged by variation in their treatment.

The work of geographical exploration has been continued in the Antarctic and Arctic Regions—in the former especially some progress has been made. Many survey expeditions have been at work during the past year in the interior of this great continent. Major Powell Cotton has explored the almost unknown region between Lakes Rudolph and Albert. Mr. Chevalier has discovered where the basins of the Nile, the Congo, and the Shari Rivers meet, near the boundary of Darfur, whilst in Northern Rhodesia our knowledge and our maps have been amplified.

During the last year the study of tropical diseases has been continued with vigour. In Uganda the Commissioners, Dr. Castellani, Colonel Bruce, and Dr. Nabarro, who were appointed to investigate the disease known as the Sleeping Sickness, have discovered, by a careful examination of every case that came under their notice, that it is due to a parasite, “*Trypanosoma*” in the cerebro-spinal fluid, and that the agent of infection is a species of tsetse fly, named the *Glossina palpalis*.

In Rhodesia, Dr. Koch has been spending the whole year in laborious and patient investigation of the African Coast Fever among cattle, and he has now reported that he has found that it is caused by a blood parasite which can be readily identified by a demonstration of the specific organism, that it is different from Texas Fever, or so-called Red Water, that it is not transferable directly, that sick animals can be stabled with healthy ones without communicating the disease, and that the disease can only be spread by ticks. Further, that the blood of animals that have recovered and become immune is not free from parasites, and that the disease therefore can be produced in healthy animals by the transfer of parasites from salted animals by means of ticks, and that though fencing, dipping, and spraying are beneficial, yet as they have only a temporary value, he recommends that these precautions should be supplemented by inoculation with the blood of animals that have recovered whenever disease breaks out in the vicinity.

The Geodetic Survey of Africa, whose inception and continuation owe so much to our past President, Sir David Gill, is being proceeded with both here and in Northern Rhodesia beyond the Zambesi. It is intended, as you are aware, to ex-

tend it northwards, more or less, probably along the route of the Cape to Cairo Railway, that projected line which to many appears, perhaps, to belong to the things of dreamland. You, however, who know South Africa well, will agree with me that in this country it has generally been found that the sanguine man has ever been the truest prophet. When this Geodetic Survey has been connected up with that of Europe, which has now been extended as far north as Spitzbergen, we shall have an arc from that point to Cape Town—the longest arc that is possible to us on this globe.

All civilised nations have found the advantage of having proper and accurate maps, and it is hoped that a useful work may now be undertaken in South Africa by a system of secondary triangulation. This work will necessarily take many years to complete; every year, however, the recorded results will be of value, as they will enable correct maps to be compiled, showing the topography and main features of the country, and the situation of the larger farms, of the most important and more populated districts in the first place, and then of the more remote parts of the country.

Professor Haddon, the late President of the Anthropological Institute, has expressed himself strongly on the urgency of anthropological research. "In view," he says, "of the decrease of the native races by the advance of civilisation and the changes in the habits of the survivors, no time is to be lost in the acquisition of scientific knowledge by direct observations.

There is wide scope and much opportunity in South Africa for such research, though I think you will agree the argument about their decrease and the use of the word "survivors" read strangely to us, who see the native races not decreasing but happily increasing in numbers, as well as in material prosperity, a fact that might, one would think, be borne in mind by many whose intentions are good, but who are swayed by emotion rather than by the cold logic of scientific accuracy.

For research into the causes and preventives of disease both in human beings and in animals, there is, as we all have good reason to know, a great field in South Africa. The various Governments here have shown commendable vigour in dealing with those terrible scourges, Rinderpest, Plague, and Red Water, and have acted in a spirit of the truest economy by securing the services of the most able scientists of the day for their investigations. When England was ravaged by Rinderpest, no remedy was discovered: the animals affected were simply destroyed, at a cost of some nine millions of money. It was left for South Africa, at a later date, when knowledge was more advanced, by the admirable work of the scientific investigators engaged on that task, to be the first to discover a preventive for that disease, a fact of which this country may well be proud.



I have mentioned Dr. Koch's great work in the investigation of cattle fever in Rhodesia. He has also at the same time undertaken researches into some other of the diseases affecting animals in South Africa, amongst them that most familiar but terrible disease which we call horse sickness, a disease by which this country loses not only many thousands of pounds annually by the deaths of valuable animals, but also the large amount that might otherwise be realised by the breeding of horses and mules. I understand that Dr. Koch is sanguine as to the result of his researches. Time alone will show whether his efforts or those of Dr. Edington and other labourers in this field have given us the much-to-be-wished-for certainty of rendering horses and mules immune from this disease.

Work is being carried on in the investigation of the other manifold sicknesses to which animals are liable in South Africa, but "science is slow," and much more time and patient research is necessary before we can arrive at what we look forward to, a period when we shall no longer be helpless and at the mercy of these devastating pests.

As to diseases affecting the human race, we have to congratulate ourselves that the interest of the community has been at last awakened, and though the necessary research may be, probably will be, costly, yet there is a strong and growing feeling that the money *must* be forthcoming, and that no further time shall be lost before commencing the most thorough investigations into the causes of and ascertaining the prevention and possible remedies of cancer and other diseases which have till now baffled the efforts of medicine. We must all admire the truly wonderful work done by the skilful surgeon, but we would all rather, if there are other means of help, do without the knife. South Africa may be proud of the fact that some of the largest contributions to assist in carrying out these researches have been made by men who have spent the best years of their life in this country.

Interesting communications were made during the past year to the Royal Society by Professor Farmer, Mr. Moore, and Mr. Walker with regard to the method of growth of cancer cells, and also by Professor Macfayden concerning the cell juices of the typhoid bacillus.

Amongst other subjects worthy of immediate research should be included the disease of scurvy, which affects chiefly the Kaffir races, if it can be shown, as some medical men believe, that it is on the increase.

There is an extraordinary lethargy in the human mind as to diseases which affect mankind, and there is a great lack of individual effort to assist in their prevention. Once the cause of a disease is ascertained, and especially in the case of a more or less deadly disease, one would suppose that the whole community would combine to remove the cause, or to take measures to render it at least less frequent. This is, however, very far



from being the case. Research with regard to malarial fever, for instance, has proved that it is transmitted to the human being by the female mosquito of the *Anopheles* genus. We know her by sight, we realise the harm she is capable of, and yet how little do we do to rid the world of this wicked lady. We know the four stages of the life of mosquitoes, we know that they are easily destroyed in the larval and pupal stages when they are lying just beneath the surface breathing through a little upright funnel perfectly visible in the still water they frequent, and yet how little effort is made by individuals in this country to exterminate them or lessen their numbers. If everyone made a point of destroying the larvae of mosquitoes close round his house, perhaps in his back yard, as well as the mosquitoes inside his dwelling, it would help in great measure to prevent disease. If the public were thoroughly convinced of this, we might expect more activity in this respect.

The great characteristic of the American people is their common sense. Realising the danger to public health from the once prevalent habit of expectoration, they have taken measures to stop it entirely in all their great cities, which are now cleaner in this respect than the metropolis of Great Britain. If you travel in the street cars of New York or Boston you will see posted up a notice to the following effect:—“Spitting is a misdemeanour; anyone found guilty of this offence is liable to a fine of one hundred dollars, or imprisonment, or both.” That may seem drastic to us, but, supported by the weight of public opinion, it has proved absolutely effective, and has undoubtedly tended greatly to the benefit of the general health of the community.

Since Pasteur proved that fermentation did not take place in the absence of living organisms, scientific investigation has established with ever-increasing certainty the germ theory, both as regards health and disease. Research has proved that what may be termed healthy ferment is at the root of plant and animal life, and that on the other hand the majority of human diseases are due to the presence of very minute living organisms. These scientific investigations have only been rendered possible within the lifetime of most of those present here to-day by the greatly increased accuracy and precision of the instruments devised by science, in the cause of science. Before we had these ingenious instruments wherewith to measure, to feel, to hear, and to see what is beyond the paltry scope of our poor human senses, the human intellect was groping in the dark. As yet we are only on the fringe of knowledge; what we know represents only an infinitesimal portion of what we may come to know, of what we anticipate we shall know. The want of accuracy has been the stumbling block of science. “The science of the Middle Ages,” says Pater, “was all divination, clairvoyance, unsubjected to our modern exact formulas, seeking, in an instant of vision, to concentrate a

thousand experiences." Even those few who had the true scientific mind were stopped by the rudeness and inaccuracy of their instruments. The great astronomical observer, Hipparchus, had to make his observations by the unaided eye; he measured time by sand or water glasses. The great Arab astronomers a thousand years ago had instruments, which they could read to single minutes only; a hundred and fifty years ago there were instruments that could be read only to seconds. Portable watches were invented less than four hundred years ago, and they are said to have varied several minutes a day. We are able now to realise that, as Tyndall said, "The domain of the senses in nature is almost infinitely small in comparison to the vast region accessible to thought which lies beyond them." It is the poverty, the inaccuracy of our senses, that has so retarded knowledge. Put, for instance, weights in each of your hands, you will find that they must vary considerably before you are conscious of the difference; compare this with the delicacy of the modern scales to be found in every assay office in this town.

We talk of feeling the extremes of heat and cold; can the inaccuracy of language go further? It is estimated that absolute cold is at about 273 deg. C. below zero, that the heat of the electric arc is probably 3,500 deg. C. above it, and that the heat of the sun may approximately be 6,000 deg. C. whilst many of the stars may be very much hotter than the sun. What a small proportion of this range of temperature can be appreciated by the human body. Can we tell without looking at a thermometer whether the temperature is at 20 deg. or at 21 deg. C.? Compare this with what science enables us to do now. Professor Langley, Secretary of the Smithsonian Institution at Washington, has invented in the Bolometer an instrument of such delicacy that it will actually register to one-millionth of a degree centigrade.

How dull is our sense of hearing compared with the instruments which science has given in the telephone and the microphone.

I suppose many of us have had at times to leave a dead animal on the veld; if you scan the heavens, within a few minutes you will see first one speck and then another appear overhead as the aasvogels collect from all directions, where they have been, perhaps, quartering the heavens. The power of human vision cannot compare with such sight as they possess, and yet by the aid of instruments we can now see beyond comparison infinitely further and more precisely than they can. It is by the delicacy and accuracy of mechanical contrivances that we have commenced to explore the regions accessible to human thought, but infinitely beyond our unaided human senses.

In my schooldays we were taught to regard heat and light as two distinct agents; now we know that they are both

radiations emitted by hot bodies in the form of waves; notwithstanding that the length of these waves is so small that we judge them by the micron or one-thousandth of a millimetre, still we can measure them, and further by means of the spectroscope, an instrument for studying the spectra of bodies on earth or in the heavens, which was first used in astronomical work some forty years ago, we can analyse those waves which affect the optic nerve. If the wave length is greater than about one forty-four-thousandth of an inch we are conscious of heat, and not light. We find that the waves that produce the sensation of light range in length from about one forty-four-thousandth to one seventy-thousandth of an inch, and as different lengths are refracted differently we see in the spectrum red, yellow, green, blue, and violet in succession, the colour depending on the wave length. Wave lengths from one forty-four-thousandth of an inch to one fifty-thousandth of an inch give red, and then, as the wave length is shorter and shorter, we get yellow, green, blue, and lastly violet. When the wave length is less than about one seventy-thousandth of an inch, there is no longer any sensation of light on the optic nerve. What happens on either side of these limits? As I stated, when the wave lengths are longer than about one forty-four-thousandth of an inch we get no light, but we get heat, and the heat waves are supposed to vary between this length and one four-hundredth of an inch.

Electric waves vary probably between one-tenth of an inch and possibly one thousand feet in length. Herz measured his electric waves at about one hundred and fifty feet in length from node to node, and the waves now used in wireless telegraphy are considerably more. At the other end of the scale beyond the ultra violet, when the waves are too small to be visible, which we find to be the case when the wave lengths are less than one seventy-thousandth or one eighty-thousandth of an inch, we find that though they do not affect the optic nerve there are still waves, and that these affect photographic plates, and have various chemical actions; we are able, therefore, now to ascertain the vibrations and the lengths of more than a thousand million different waves, all travelling at the same speed of over 186,000 miles per second, of which only about thirty thousand are visible to us. Truly this is an eloquent tribute to the accuracy of scientific instruments. Sir Isaac Newton in his theory of gravitation contended that every particle of matter in the universe attracts every other particle with a force that diminishes as the square of the distance increases. How could this be proved or disproved? Many doubted it. Everyone is aware of the force of gravity, but many eminent scientists believed that this force resided in the earth's centre. The truth of Newton's theory was proved by an apparatus of such extraordinary delicacy and accuracy that it could measure the attraction of a globe of lead about a foot

in diameter upon two small balls attached each to one end of a light horizontal rod suspended at its centre by a very fine thread. Such was the proved accuracy of the measurements made with this delicate and extremely sensitive instrument, that it led to the computation of the density of the earth, which is now proved to be five and a-half times the density of water, and from this fact, as we know that the density of the crust of the earth is only about half this amount, we get an additional proof of the fact arrived at by other means, that near the centre of the earth matter must be compressed to a density far exceeding that of iron; in other words, that the centre of the earth is not a hollow full of fire, as used to be believed, but a solid, more rigid than steel. Those who go down to the deep in mines know well that the temperature rises as we descend. This rise in temperature somewhat varies in different localities, but if we consider that every cubic foot of earth weighs perhaps one hundred and fifty pounds or more, it is certain that the heat some ten or twenty miles below the surface must be very great, and must be still greater further down, but yet every evidence goes to prove that notwithstanding the high temperature necessarily caused by the superincumbent mass, the interior of the earth is kept solid by the enormous pressure.

We are able to compute not only the density of the earth, but also that of the sun and the other members of the solar system.

We know that the density of the sun is about one-fourth that of the earth, and about forty per cent. greater than that of water; that the density of Jupiter is only about one-third greater than that of water, and that the density of Saturn is even less than that of water. Not only do we know the density of the planets, but we know their size and mass, and in some instances their period of rotation. We are able by the accuracy of our instruments to weigh, to measure, and to analyse them. How have these results been obtained? They have been arrived at by years of work, of patient and accurate observation, and of the most intricate and complicated mathematical calculations. The weight of a planet is arrived at either by measuring the deviation in the orbits of the planet next to it, caused by its attraction to them, from which the force of the pull can be determined and consequently the mass, or secondly in the case of a planet which has satellites revolving round it, astronomers observe the attraction of the planet on its satellites and so determine its mass.

It is estimated that the human eye at its best cannot distinguish more than 5,000 or 6,000 of the stars out of all the millions that there are. Reflecting and refracting telescopes enable us to see many millions of them, but a photograph telescope with a specially made object glass will reveal on a photograph stars too faint to be seen through any telescope up to

hundreds of millions in number.

Photography is now in constant use for studying the spots on the sun, the comets, and the nebulae. In connection with the study of the sun-spots, by the use of the spectroheliograph, invented by Professor George Hale, which is an instrument for taking photographs of the sun by the light of a single ray of the spectrum, astronomers have found that calcium is the most noticeable constituent of the gas eruptions that are for ever taking place on the photosphere of the sun. It is by the spectroscope that astronomers are enabled to determine what the heavenly bodies are made of, because if the light of an incandescent body passes through a gas which is cooler than that body, the spectrum from the solid body will be seen crossed by dark lines which vary according to the nature of the gas through which the light has passed. It was by spectrum analysis that the red prominences in the sun were discovered to be masses of glowing hydrogen. By the spectroscope again it is possible to determine whether heavenly bodies are advancing towards us or receding from us, for an advancing star gives out somewhat shorter wave lengths of light, whereas a star receding from us gives out longer ones. The position, therefore, of the lines in the spectrum reveals the motion of the star. Variable stars, that is to say, stars whose brilliancy varies in many cases by regular periods, have been for many years the subject of careful study. It is now ascertained that this variation is caused by the fact that what appears to be one star as seen even by the most powerful telescope, is really a double star, the one revolving round the other. This has been discovered by the fact that the spectrum of the star is a double one, the lines of one now covering and now receding from the lines of the other.

In the case of the variable star Beta Perseior Algol it was noticed that at intervals of about two days and twenty-one hours it fades away for a few hours. It is now known by means of the spectroscope that a dark planet revolves round this star and partially eclipses it. Surely this discovery may be hailed as a veritable triumph of science due to extraordinary accuracy of observation and the extreme precision of scientific instruments. Distance makes no difference to the spectroscope. If enough light comes from the star to enable its spectrum to be analysed, though that light may have been hundreds of years on its way to us, travelling at the rate of over one hundred and eighty-six thousand miles a second, still the analysis reveals to us the constitution of the star. As the usual units of measure would be quite inadequate to deal with the immense distances in the solar system, astronomers use the mean distance of the earth from the sun as a unit of measure for determining the distance between the planets. The measurement of this unit necessarily involves the most difficult and intricate problems, and astronomers are not as yet satisfied with the results.

The distance as computed by the following four different methods, namely, measure of parallax, by the velocity of light, by the swing of the moon, and by the relations between the mass of the earth and that of the sun, varies between 93,113,000 and 92,958,000 miles. This is an eloquent testimony to the precision and accuracy of astronomers and their instruments, and perhaps the fact that astronomers are not satisfied with such results is a testimony more eloquent still.

I have dealt with these instances of what precision and accuracy can and has been achieved in astronomy, because, not only do they show that truth is never dull, but they appeal with such force to the imagination. When we look up into the heavens at the two bright stars near the Southern Cross and consider that, as far as our knowledge goes at present, one of them, Alpha Centauri, is the nearest to us of all the stars in the heavens, and that its distance from us, as far as it is yet determined, is 275,000 times that of the sun from the earth, we appreciate the immensity of the universe and the wonders of science.

The education of the past has been so defective in scientific training that very few parents even to-day can answer with accuracy the many questions propounded by every curious and enquiring child. But now that we have attained to a certain amount of exact knowledge as to the laws and facts of nature, at least we should in South Africa insist that every child should be taught the simple facts of science, the immutable laws of nature, truthfully and accurately. To learn is easier than to unlearn, and the untruths that have been instilled into human beings for many centuries past have not only caused needless misery, but have materially retarded the progress of the human race.

At the northern end of this vast African Continent more than 2,000 years ago Pythagoras instructed his pupils as to the motions of the earth. Aristarchus evolved the proper methods of calculating the distance of the sun and of the moon. Eratosthenes calculated the circumference of the earth. Hipparchus discovered the precession of the equinoxes; and Hero invented the steam turbine, re-invented only lately by de Laval. It is true that the conclusions of these great minds were not always accurate, because they had not the delicate and accurate instruments that have enabled men of science of the last hundred years to arrive at far more precise results, but their methods were scientific, notwithstanding.

Let us hope that, emulating these sages of antiquity from the time of Thales to Galen, there may be many scientific workers in this southern part of this same great continent who may, with the advantage of the accuracy and delicacy of modern instruments, achieve, by honest record and truthful research, results that may serve humanity by opening up fresh paths of human activity, always mindful of the fact that the



highest function of science is the true interpretation of nature and its laws. Huxley maintained that no boy or girl should leave school without possessing a grasp of the general character of science, without having been disciplined more or less in the methods of all science.

"That man," he says, "has had a liberal education who has been so trained in youth that his body is the ready servant of his will, and does with ease and pleasure all the work that as a mechanism it is capable of. Whose intellect is a clear, cold logic engine, with all its parts of equal strength and in smooth working order, ready, like a steam engine, to be turned to any kind of work and spin the gossamers as well as forge the anchors of the mind; whose mind is stored with a knowledge of the great and fundamental truths of nature and the laws of her operations; one, who, no stunted ascetic, is full of life and fire, but whose passions are trained to come to heel by a vigorous will, the servant of a tender conscience, who has learned to love all beauty, whether of nature or of art, to hate all vileness, and to respect others as himself."

This Association would do well to lay stress on the necessity of having the men and women of to-morrow, the children of to-day, educated on such a basis. Anyone who has had to do with the training of youth will bear evidence to the natural tendency of a child's mind to inquire into and even be fascinated by the study of flowers, of fish and animal life, and of the heavens. This inclination has been too often in the past stunted and deflected by the ignorance of their teachers, but let us hope that this will not, cannot, occur in the future, now that the work of the great scientists of the past fifty years is bearing fruit. How few people even yet really appreciate what we owe to those great minds, and what a vista of intellectual and material enjoyment they opened up. As Lord Avebury, in an essay on Professor Huxley, puts it:—"Huxley was one of the foremost of those who brought our people to realise that science is of vital importance in our life, that it is more fascinating than a fairy tale, more brilliant than a novel, and that anyone who neglects to follow the triumphant march of discovery, so startling in its marvellous and unexpected surprises, so inspiring in its moral influence, and its revelation of the beauties and wonders of the world in which we live, and the Universe of which we form an infinitesimal part, is deliberately neglecting one of the greatest comforts and interests of life, one of the greatest gifts which we have been endowed with by Providence."

"No man," says Professor Drummond, "can study modern science without a change coming over his views of truth; what impresses him about nature is its solidity, he is standing upon actual things among fixed laws."

Every scientist lays stress on the necessity of truth. "The fundamental characteristic," says Professor Ira Remsen, "of

the scientific method is honesty. In dealing with any question science asks no favours. The sole object is to learn the truth, and to be guided by the truth. Absolute accuracy, absolute fidelity, absolute honesty are the prime conditions of scientific progress." This is the keynote of science. Veracity: that is what science demands of its followers, whether they are busied in experiments or researches, in recording minute facts, or in generalisations from those facts—absolute truthfulness.

It is self-evident that if by what Huxley calls a liberal education this habit of mind of honesty is engendered in youth, the result to the race must be far-reaching and beneficial in the extreme in every phase of human life and activity. The subject of Technical Education is one that we are all interested in, and the vital importance of a training in scientific principles to fit men for each and every profession has been widely advocated by statesmen, manufacturers, and scientists. It has been well and forcibly supported by the Press. Its necessity has been recognised here in Johannesburg with the thorough practicality that we always expect from this enlightened community. I need, therefore, not enlarge on it. In the words of William Barton Rogers, to whom was mainly due the origin of the Massachusetts Institution of Technology at Boston, "We believe that the most truly practical education even in an industrial point of view is one founded in the thorough knowledge of scientific principles, and which unites with habits of close observation and exact reasoning a large and generous cultivation." We have come to recognise, too, a truth, the importance of which cannot be over-estimated, the necessity of giving to the professors and teachers of such institutions ample time and opportunity for individual research. I need scarcely point out to an eminently practical community like that of Johannesburg the opportunity they have of forwarding their own interests by cash contributions, not necessarily of large amounts, and which could be limited as to period, for the purpose of furthering research into problems affecting objects they may have in view.

One valuable feature of the training in the Technical Schools of Boston and Cornell, in America, and of Berlin and Zürich, in Europe, is worthy of notice, and that is that many of the lectures are given by men in the full and regular practice of their professions. The student has the advantage of knowing and becoming personally known to men thoroughly cognisant of the theory and practice of the profession he is about to enter, and this social and intellectual intercourse must prove of lasting and mutual benefit. The man practising a profession or trade is always on the look-out for likely young men to assist him, whilst the professor and regular teacher is ever proud of placing out his promising pupils to the best advantage. The human element plays a large part in education; of the making of books there is no end, but often the truth is



not in them. If there could be a comprehensive educational series "hall-marked" by some competent body, guaranteeing it as being accurately truthful in its statements and its arguments, education would soon be in a more forward condition. I sometimes wonder if the press ever realises the dominion it might possibly have had. We all recognise the great influence it has now, but just think for a moment how that influence would be enhanced, what the power of the press over every one of you would be, if you knew that every statement that you read, whether it were in books, in the papers, or in a magazine, not avowedly fiction, was absolutely and accurately true! The day of universal scientific accuracy in every-day life is not yet, but the time may come when the motto, not of science alone, but of every human being, shall be "Humility and Truth."

**SECTION A.**

**ASTRONOMY, CHEMISTRY AND METALLURGY, MATHEMATICS,  
METEOROLOGY, PHYSICS.**



## SECTION A.

### PRESIDENT'S ADDRESS.

#### THE METALLURGY OF THE WITWATERSRAND.

By JOHN R. WILLIAMS.

(Plates I. and II.)

I fear my colleagues in making their choice have given me an impossible subject to deal with this morning—viz., the Metallurgy of the Witwatersrand. In the production of gold there is no competition, and so, there being no walls of China surrounding the metallurgy of this country, the members of the many useful scientific societies on these fields have been only too willing to contribute papers on any new discovery or departure from routine practice.

I find it, therefore, quite impossible (without reiterating statements made and quoting from papers written by others as well as myself on this question, so important to these and other goldfields) to attempt to do justice to the subject indicated by the title of this address.

Gold has always been, and probably always will be, the most sought after of all the metals, on account of its intrinsic value and commercial importance; yet, notwithstanding this, the winning of it has, up to the last half-century or so, been conducted in the most primitive fashion.

So far as our knowledge goes, the Ancients were limited to washing it out of the sands or crushed rock, and refining the product by fire. This, together with the use of mercury in some form to assist collection, has remained for ages the extent of the knowledge of the subject.

The first introduction of a method for the further extraction of the precious metal was that of dissolving the gold by chlorine gas after calcination, which is still in use in a similar form to that when first adopted, being called the Plattner process, after its discoverer, and occasionally modified by the substitution of bromine or iodine solutions, etc.

To within the last 15 years or so this represented practically the only hydro-metallurgical method in use, and, being a process which even in most favourable cases entailed a cost of over 15s. per ton, its sphere of usefulness was limited greatly, and it was generally adopted only after some form of concentration.

Subsequently a good deal of experimenting was made

with a view of making use of the well-known properties of cyanide of potassium as a solvent for gold which had been discovered by Prince Bagration, and amongst those who worked upon this may be mentioned the names of Janin, Rae, Simpson, etc.; but it was left for MacArthur and Forrest to first bring it to a practical form and to demonstrate that it could be commercially applied to the winning of gold, and by them it was first introduced on the Witwatersrand Gold-fields in 1889; since then it has undergone enlargement and modification, until it stands to-day in the position of being the most important process in the Metallurgy of Gold.

Having now given you a brief description of the earliest history of metallurgy, I will now take the modern practice of a mine on the Witwatersrand.

The ore from the Main Reef series of the Witwatersrand has been too much written about to need any lengthy description.

As is well known, the ore is a pebbly conglomerate, and the interstices are filled up with a cement which is the only mineralised part of the rock. In some exceptional cases the pebbles have been known to be mineralised and even to consist of pyrites, but these instances are not numerous. This cement is mostly siliceous matter and iron pyrites; it adheres very strongly to the pebbles, making it necessary to pass everything through the mill.

The composition of the ore is approximately about 3 per cent. iron pyrites and 97 per cent. silica, with occasional traces of other minerals.

I recognise that there are a large number of scientific gentlemen present, who are fully conversant broadly with all the methods in use for the recovery of gold, but at the same time it can hardly be expected that all of them are familiar with the details of the Metallurgy of Gold as practised on these fields. For those who are laymen in the science of metallurgy I think a very brief glossary of some of the terms used here may be found of assistance.

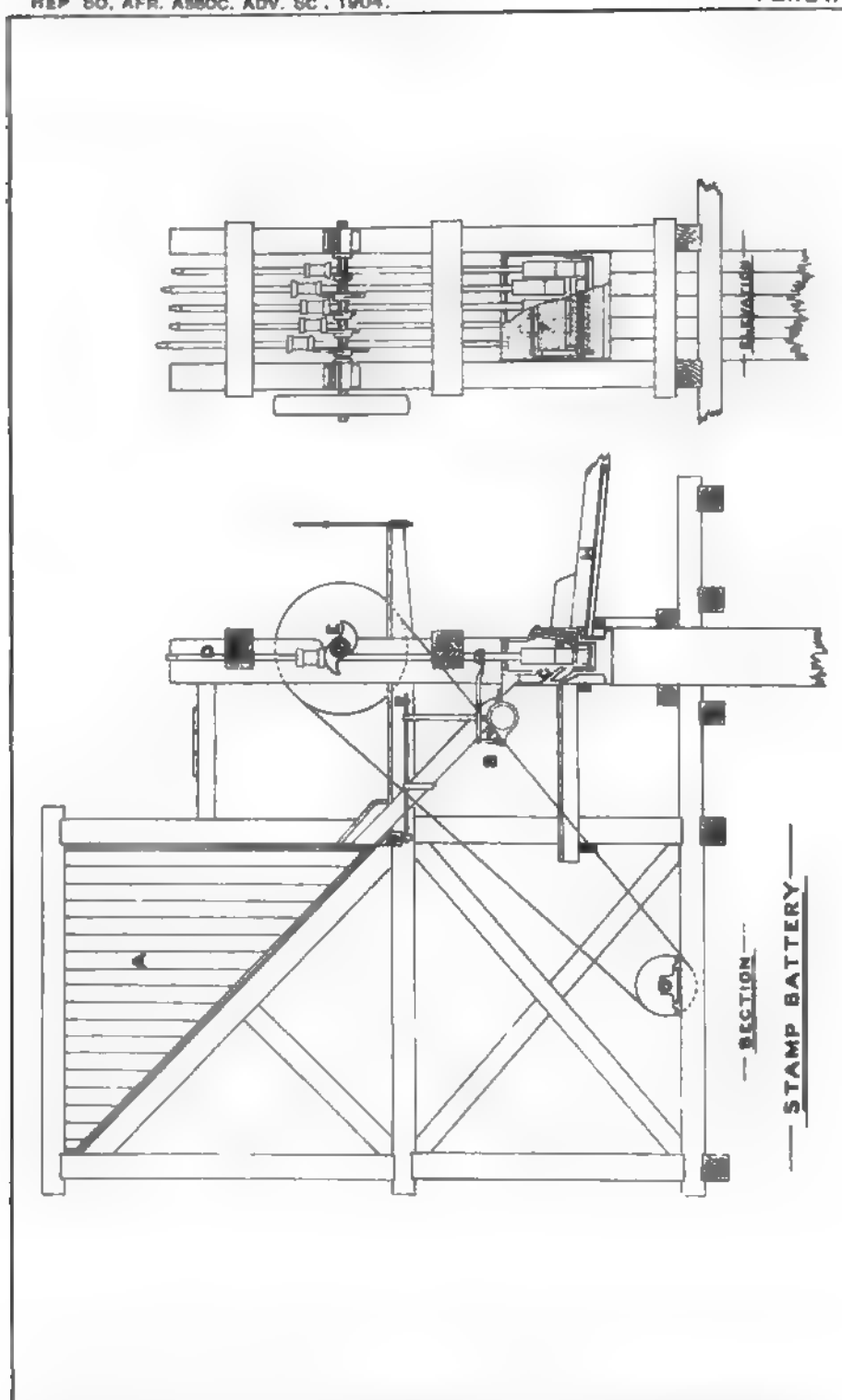
*Metallurgy.*—"The art of extracting metals from their Ores."—*Percy.*

*Ore.*—The terms "Ore," "Quartz," and "Banket" are applied to metalliferous matter in its natural state.

*Concentration.*—The name applied to any mechanical operation which separates the metalliferous particles from the earth, stone, quartz, etc., with which they are mixed. As these metalliferous particles carry many times the amount of gold that was contained in the original ore, they are called concentrates from the fact that the gold has been concentrated into a small bulk.

*Tailings or Sands* are the leachable sandy particles of crushed rock after the free gold has been extracted by amalgamation and the concentrates by special machinery.





*Pulp.*—By pulp is meant the mixture of crushed ore with concentrates, slimes, and water, as they leave the mill plates.

*Slimes.*—The unleachable clayey portion of the ore with some very fine sand, which remains in suspension for some time in water.

*Residues* are the tailings, concentrates, and slimes after the gold has been extracted by any process.

After the ore has been hauled from the mine and the necessary hand picking of waste rock on revolving tables, belts, or other methods performed, it is taken to the battery, which is also known as the quartz mill.

Since the gold is in a very fine state of division, several thousand pieces being sometimes required to weigh one grain, it is necessary to crush the ore very fine before the gold can be extracted. Of all the machinery yet invented, the stamp mill must be acknowledged the best pulveriser, and is the only machine used on the Rand. This machine and the operations connected with it are so well known that for most readers it would be unnecessary to give any description of it, but for the benefit of the uninitiated a few remarks may be interesting. The ore, as brought from the mine, after picking out as much as possible of the sandstone which carries little or no gold, is passed through a stone-breaker, which reduces it in size so that it will pass through a 2-inch mesh. It is then by means of trucks taken into the mill and dumped into the ore-bin "A," which has an automatic arrangement attached called a feeder "B," by which a constant supply of ore is kept in the mortar-box "C." The stamps "D," of which there are usually five in a mortar, are lifted by the cams "E," and then fall with their full weight on the ore. The particles which have been sufficiently reduced in size are continually removed through the screen "F" by the aid of water, which continually flows into the mortar-box. Mercury is from time to time added in the mortar-box. This amalgamates with the gold, which is caught on the amalgamated copper plates "G" and "H" inside and outside the mortar-box (see Plate I.).

Great judgment is required in the amount of mercury used, as if too little is added the amalgam becomes hard and brittle, and is easily carried off the plates by the sharp stony particles, whereas if too much mercury is used the mercury liquates in tears, rolls off the plates, carrying gold with it. The amalgam on the outside plates or coppers is taken off daily by the aid of an iron scraper, and after grinding in a Wedgewood mortar with an excess of mercury, it is squeezed through a piece of fine canvas or chamois leather, which allows the mercury to pass through its pores, whilst the gold is retained as a pasty amalgam, consisting of from 25 to 30 per cent. of gold, the remainder being mercury with some



impurities. The inside coppers are taken out weekly or when required, and cleaned off in the same manner as above. Once a month the sands in the mortar-box, which contain a large percentage of the coarser gold, are taken out and ground with mercury. This amalgam is retorted in a strong cast-iron cylinder called a retort, which is placed in a strong fire, the heat of which volatilises the mercury; the mercury vapour is led through a condenser, where it is caught for re-use in the mill. When the retorting is finished, the door is screwed off, and the now spongy gold is melted with a suitable flux in a plumbago crucible, and cast into bars or ingots, which usually contain from 80 to 90 per cent. of gold, the difference being principally silver, which is nearly always associated with native gold. By the stamp mill five tons of hard rock per stamp per day can be crushed so as to pass through a mesh having 700 holes to the square inch, at a cost of 3s. per ton including maintenance. The amount crushed depends upon the hardness of the ore, the number of holes to the inch in mesh, the weight of the stamps, and the height of the drop.

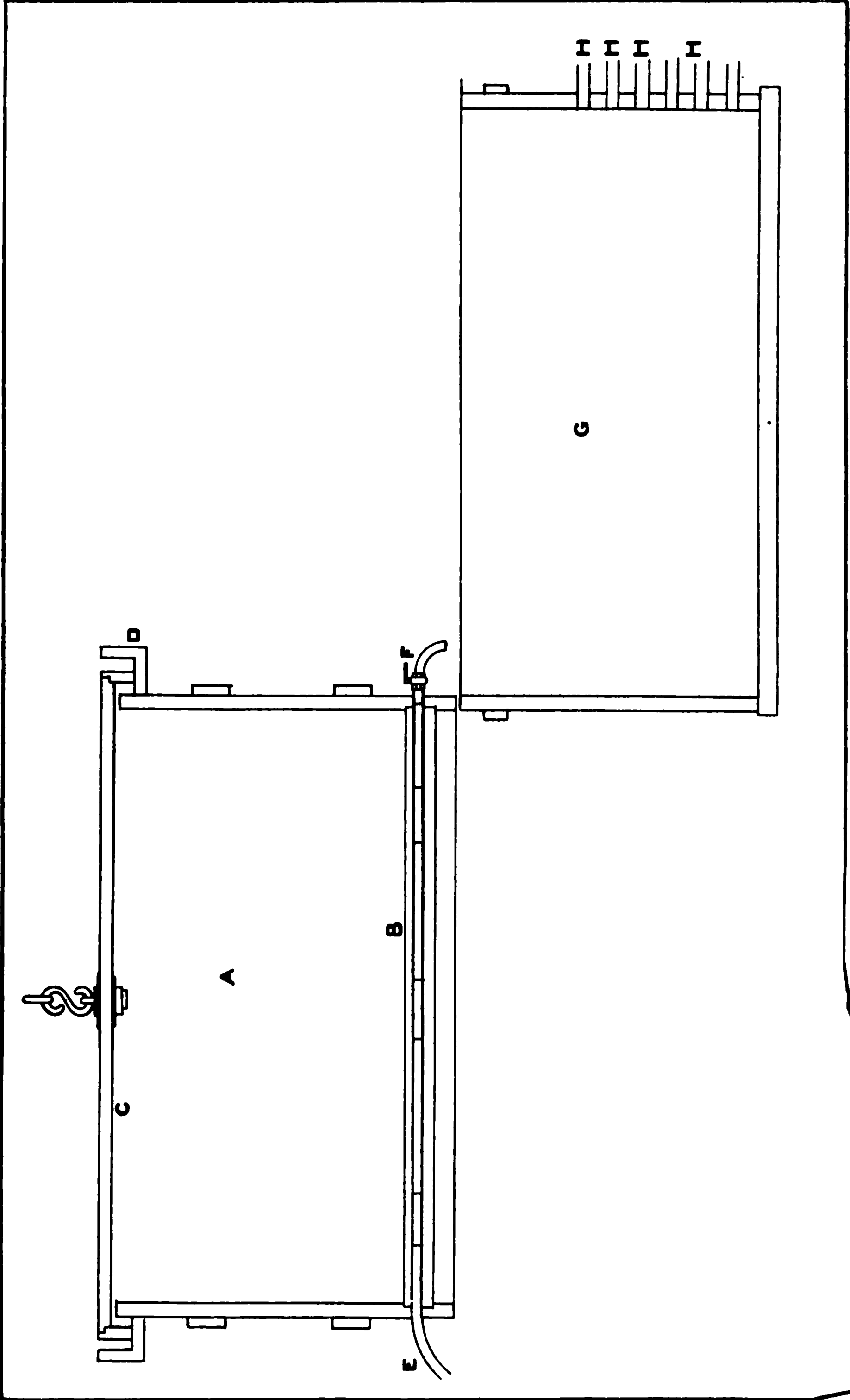
There are four methods at present by which the pyritic pulp may be treated, viz.:—(1) Concentration; (2) Concentration and treatment of tailings by cyanide; (3) Direct treatment by cyanide; and (4) Classification and treatment of the various products according to the time required by the cyanide to dissolve the gold.

*Concentration.*—As most of the leading metallurgists on the Rand are of opinion that the fine concentration and chlorination of Rand ores is usually an unnecessary process owing to the cheap solvent for gold possessed in cyanide of potassium, it will be sufficient to say that it has for its object the removal of metalliferous particles from the matrix of quartzite by the use of special concentrating machinery, and if it were possible to do this effectively it would certainly be the right procedure to adopt, but as rarely more than 40 per cent. of the gold is extracted by this method, and in many cases not more than 40 per cent. of this results in a profit, it has generally been discarded in favour of the more profitable treatment by cyanide subsequently described.

*Recovery of Gold from Concentrates.*—There are two processes used to extract gold from concentrates, which vary in value from 3 ozs. to 20 ozs. per ton:—(1) Chlorination; (2) Cyaniding. The average of Rand concentrates is from 4 ozs. to 5 ozs.

*Chlorination.*—This process was first introduced by Professor Plattner, of Freiberg, Saxony, and is acknowledged to be the most perfect method for extracting gold, as, unlike the cyanide process, it is applicable to practically all classes of ores. The process is based on the fact that when chlorine gas is brought into contact with gold-bearing substances, the





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gold is converted into a soluble chloride of gold, which is easily dissolved in cold water, from which it can be precipitated by either sulphate of iron yielding metallic gold or by sulphuretted hydrogen yielding sulphide of gold. These precipitates are then dried and melted with a suitable flux to obtain nearly pure gold.

The conditions necessary for the economic working of the process are: (1) The gold must be in a metallic state and finely divided; (2) there must be no other substance in the ore which will unite with chlorine, as this would cause waste of the gas; (3) there must be no substance present which will prematurely precipitate the gold before the solutions are drawn off. As the material subjected to chlorination is usually concentrates, which only require roasting to convert the base metals into oxides (so as not to unite with chlorine) and prepare the gold in a suitable condition for chlorination, they present no difficulty, and an extraction of 97 to 99 per cent. is easily obtained.

The concentrates are first dried by the waste heat of the furnace, after which they are introduced into a reverberatory furnace, where they are calcined so as to expel absolutely all the sulphur, converting all the sulphides into oxides. The charge is then withdrawn from the furnace and thrown on what is known as a damping floor, where it is carefully damped. Usually 5 per cent. of water is added, which will render it so that on handling no dust is formed, and a handful pressed will form a lump without moistening the hand. The object of this damping is, firstly, to render the charge light so that it does not pack in the tank, secondly, chlorine gas in the dry state does not dissolve gold, and it is therefore necessary to be very careful in damping the calcined or roasted ore. This is now transferred to the tank "A" (see Pl. II.), having a perforated false bottom, which is in fact a carefully perforated filter, "B." A lid "C" having a water joint "D" is put on, and chlorine gas is forced by pressure from the generator through the leaden pipe "E." The gas diffuses through the ore, and when the charge is saturated (which can be ascertained by its appearance at the top of the tank) it is turned off and the charge allowed to stand according to the time required—18 to 24 hours being usually sufficient. The cover "C" is now removed, and sufficient water added to thoroughly saturate the charge, which after standing for some time is drawn off through the cock "F" at the bottom and run into the precipitating vat or tank "G." Sufficient water is further added to the charge to wash out all the soluble gold chloride; these washes are added to the other in the vat "G." The gold chloride in solution is precipitated by the addition of sulphate of iron (green vitriol). When the gold precipitate is quite settled, the solution is drawn off through a series of cocks at the side,

and the precipitate carefully filtered, dried, and melted with a suitable flux, and cast into bars or ingots. This gold is about 970 fine, which means that 970 parts per 1,000 are pure gold. This process from a scientific view is as perfect as it is possible for any metallurgical process to be, for 96 to 99 per cent. of the gold contents of the concentrates can be extracted by it; but from a commercial point of view, owing to the large amount of chemicals required, which have to be imported from Europe, and the high cost of fuel, it has, in many cases, had to give way to the cheaper, although less perfect, cyanide process.

Having briefly touched upon the preliminary gold extraction processes, I shall now deal with the cyanide process, which, with the exception of the stamp mill, may be justly said to be the only metallurgical operation on these fields. This we learn from the Chamber of Mines' returns, which show that whereas 64.20 per cent. was extracted by the mill, and 35.16 per cent. by the cyanide process, only 0.64 per cent. was extracted by the chlorination process.

The pulp after leaving the plates is led by a launder to the tailings wheel, which elevates it to another series of launders, and these convey it first over a set of spitzlütten, where the separation of about 10 to 15 per cent. of a rough concentrate takes place, including all the coarser particles of sand and pyrites, to which it has been found advisable to give a prolonged treatment by cyanide.

From these the pulp flows on to a series of spitzkasten, where the separation of the bulk of the slimes is effected; these slimes flow over to another series of spitzkasten, where the bulk of the water is separated, and flows away practically as clean water to the return water dam.

That portion effluent from the lower discharge pipe of the sands spitzkasten is led by a hose into the sands collecting tanks, and some care has to be exercised here in the filling of the tanks, as the object is to eliminate as much of the water-borne slimes as possible, so as to obtain as leachable a product as possible. The tanks are fitted with slat gates, which have a roller blind of canvas; this serves to make a good joint of the various slats and also helps to regulate the height of the overflow. The effluent from these gates flows away by launders over the return spitzkasten in order to save any sands which may have escaped from the tanks: these then go back to the tailings wheel, while the effluent overflows and joins the rest of the slimes pulp going to the slimes works.

The filling of the sands tanks is quite an important operation, as it is necessary to obtain clean leachable sands if the subsequent operations are to be of the most satisfactory nature.

In order to obtain this desired separation of the slimes,

the gates have to be regulated very nicely, and as in spite of all care (the slimes having so great a tendency to settle in the already lime-hardened mill water and requiring to be constantly stirred up) some sands' will necessarily pass out of the tanks. Attention to this detail is important, for if the sands are in excess and beyond the capacity of the return spitzkasten, a great deal of annoyance may be caused by blockages of the pipes and sands sent down to the slimes works, causing extra wear on the sludge pumps, besides affecting the results obtained there. On the other hand, if the gates are kept too high and the slimes not sufficiently stirred up they will settle in layers; this is to be avoided, as the mass does not get sufficiently broken up in lowering, and though perhaps not interfering with the rate of leaching, these slime lumps which have been formed in the settlement do not get properly treated owing to their impermeability, and the gold which should have been obtained from them is sent to the dump.

There is nothing of any particular importance to be said concerning the concentrating spitzluten; their construction is well known, and they can be easily controlled to give any desired degree of concentration, if such a term can be used ever, rather apt to give some trouble through the wearing of ever, rather apt to give some trouble through the wearing of the sharp sands on any metal, and for this reason it has been found advisable not to regulate them with a valve. There are many substitutes, however, and the usual way is either to use a nozzle with the exact opening required, which has to be renewed frequently, or insert a wooden plug with a hole bored through it.

The collection of these concentrates requires no further attention than occasionally shifting the launder leading to the tank so as to distribute them with some evenness throughout the tank; for the rest, there are no slimes to clog the leaching, and the treatment being lengthy the same care is not needed as in the case of the sands.

In regard to the treatment of these concentrates, the only difference between this and that required for sands is one of time, and the amount of solution used, which is a matter of experience entirely, and probably no two works will give exactly the same treatment. If not too well known already, a rough outline may be given of the usual practice on the Rand.

Generally speaking, where double treatment is used it is usual to first pump on about 20 per cent. of the weight of the charge (which is usually 400 tons), that is, 80 tons of weak solution; this serves the double purpose of taking up most of the cyanicides present, and of forming a buffer between the strong solution to follow and the water held in the sand after draining; by this means the dilution by capillary attraction, etc., is partly avoided.

This solution is partly drained to waste to avoid an excess stock of solution in the sumps, care being taken in discriminating when this solution should be taken into the general stock, as containing sufficient gold. With precipitation up to its present standard, it is now the practice to send none of this to waste, but to retain it, if necessary in a separate sump, and to substitute it for the old customary water wash at the end of the treatment.

When all this solution is drained off as dry as possible about the same quantity of strong (0.3 per cent.) is pumped on, and also allowed to drain off; a vacuum pump being employed to assist this leaching in the upper tanks, as there the sand is packed rather hard, and a little such assistance is beneficial. After this the charge is ready for lowering. Of course, in the case of concentrates the treatment is more lengthy, as almost half the total treatment is performed in the upper set of tanks, whereas in a plant where it is not considered advisable to adopt double treatment this part of the operation is carried out in the lower tanks.

After lowering, another 80 tons of strong solution is pumped on, which after standing for a time is drained off; this is followed by a similar quantity of a solution of medium strength (about 0.25 per cent.); after this as much weak solution is put on as time will allow, and if the stock of solution in the sumps permits, a small water wash finishes the operation.

The total amount of solution used is about ton for ton of sands treated, and for concentrates about 3 tons of solution per ton treated, but as in general practice it is found that the longer the treatment the higher will be the extraction (within certain limits, of course), it is the aim of every Cyanide Manager to give each charge all the treatment that is possible with the plant at his command.

A very important item in treatment is the thorough draining off of each solution before adding another, the benefit of which is most marked, being probably due to the contact of air drawn in for one thing, and also because it is a better principle in the after washing. It certainly takes up some of the time for treatment, but the gain is far greater than by putting on more solution in the same time.

The rate of draining off the solution is regulated by the capacity of the precipitation boxes, which are usually such as to allow of a maximum of 5 tons an hour from each tank.

The solutions are classified in draining through the precipitation boxes, and tests are taken frequently to ascertain the percentage of cyanide contained. To illustrate this classification, the actual practice on one plant is to send all above 0.2 per cent. to the strong storage sump; that under this, but above 0.1 per cent., goes to the medium sump, while all the solution under 0.1 per cent. is either sent to the weak, or divided further between the so-called weak and

waste sumps. These figures are not at all arbitrary, as the practice will differ on the various plants and according to the nature of the sands treated; they are merely given to show the method, for actual experience alone will determine the most advantageous system.

The method of precipitation of gold from leachings of sands and concentrates may be taken as being well known, as it consists of simply bringing the solution into contact with zinc in the form of shavings, this form being adopted for the purpose of exposing as large as possible a surface of the zinc to the action of the solution, which by an exchange takes up the zinc in solution and deposits the gold in its place. There are a few points, however, which might with advantage be touched upon, as they are all factors of some importance in the complete success of the operations.

Unsatisfactory precipitation is attributable to two causes:

(1) The presence of soluble sulphides in the solutions, which may be due either to the impurities in the cyanide used or to the decomposition of the pyrites in the rock. This is counteracted by the usual practice of continuously dripping in a solution of lead acetate, which besides taking up the sulphides puts a coating of metallic lead on the zinc; this acts as a voltaic couple, and so materially assists the deposition of the gold in some instances.

(2) Excess of alkalinity, which may be either lime or caustic soda. In reduction works, where there is a slimes plant, caustic soda is rarely used, as it militates against the settlement of the slimes. In other plants it is sometimes used, but if used to excess the precipitation will suffer. In regard to lime, the addition of slimes plants has created a necessity for its use in large quantities, and by some mischance it may happen that the sands and concentrates get too large a proportion; but as this subject is discussed later when dealing with slimes, no more need be said at present. The detrimental action in this case is to form a protective coating on the zinc, which then ceases to be active, and hence requires treatment with acid. This trouble will of course rectify itself in time if the cause (*i.e.*, the lime feed) be removed, but it may be more expeditiously remedied by the addition of acid to the sumps; however, stress should be laid on the fact that the operation requires a great amount of care, and should only be undertaken in cases of actual necessity.

The presence of organic matter will also cause trouble with precipitation. A certain amount of this will always be found, mainly due to the fact that the water supply is practically all surface drainage, and also in the mines there is frequently a cleaning up of an old stope or a sump, which is sent to the mill, and is always the cause of at least some temporary trouble.



It is, of course, assumed that all the solutions contain some free cyanide, which is necessary for precipitation. There is an exception in the case of the first solution draining off the tanks, but this is either mixed with other weak ones and so rectified, or else it may be treated separately by other well-known methods, which are noticed later.

*Slimes.*—Before proceeding to give details of the present-day method of treating slimes, it may be well to note that there are many advantages accruing from the treatment of slimes beyond their conversion from a waste product to a source of profit. These may be termed the indirect advantages on account of their being absent from the profit accounts of the mine, and in consequence are therefore apt to be overlooked.

A good deal might be written on the subject, but for the purpose of this necessarily curtailed paper it will be sufficient to summarise as follows:—

1. A great saving of water is effected, as by the use of lime the water can be at once returned to the mill, whereas formerly the slimes had to be settled in large dams, thus affording an enormous area for evaporation. This saving in water amounts to not less than 40 per cent., a number actually computed from figures kept specially for this purpose: this is of the greatest importance in a district like the Rand, where the supply is limited.

2. The alkaline water returned to the mill has been proved to increase the percentage of gold caught by amalgamation by as much as from 5 to 8 per cent., and it should be borne in mind in referring to this that every ounce caught in the mill is 100 per cent., whereas if it leaves the mill in the tailings an extraction of 80 per cent. is considered satisfactory.

3. The cost of building dams to hold the untreated slimes has disappeared from the mill expenses, to which it was formerly charged, being now included in the cost of slimes treatment.

4. The sands and spitzkasten concentrates being in an alkaline state need no preparatory washes, thus there is more time for leaching in the same plant; this is naturally accompanied by a saving of cyanide and an increase in gold extraction.

5. There is a larger percentage of actual sands caught in the leaching plant, and in addition a more leachable product is obtained; this is due to the fact that the presence of sands is detrimental to slimes treatment, and while it may have been run off into a dam unnoticed, it is not so in a slimes plant, where steps are at once taken to rectify it.

The foregoing will be better appreciated when it is stated that whereas in some cases the direct profits from a slimes plant have only figured as a matter of, say, £100 per

month, the indirect profits have been computed to run into some four to seven times this amount.

In the treatment of slimes the first thing to be considered is the proper separation of the slimes from the leachable sands. With a slimes plant in operation it is no longer necessary or advisable to try to obtain a higher percentage of the pulp leaving the mill in the collecting tanks, as with the more perfect elimination of the non-leachable slimes, much higher extraction results can be obtained. It is therefore now the practice to reverse this, and only stop short of getting sands into the slimes plant; to this end the slat gates are kept very low, and the hose filling pipes are opened out to obtain a force to wash out slimes that would otherwise settle in the collecting tanks. From this it follows that the return spitzkasten is run up to its full capacity, and in some cases it has been found advisable to increase their extent.

The settlement of the slimes is effected by adding lime to the pulp leaving the mill. It is not intended here to enter into any theory to account for this phenomenon, and I shall content myself with the mere statement that the slimes will settle in any water that has a certain degree of hardness, whether it be caused by acidity or alkalinity.

There are three means adopted of rendering the mill water hard by the addition of lime, which are as follows:—

1. Adding it to the rock before crushing.
2. Adding it to the launder leaving the mill by means of an automatic mechanical feed.
3. Adding it in the form of milk of lime to the launder.

This addition of lime is quite an important matter, as will be seen, and there is a good deal to be said in favour of each method. The first is certainly the simplest, as it usually takes the form of adding the necessary amount to each truck going to the mill, or periodically adding a certain quantity to the chutes above the feeders in the mill. The drawbacks to this method are in the first place that the mill manager in some cases objects to it on the debateable ground that it affects the mill plates, and in consequence the percentage obtained by amalgamation, against which, however, we have the authority of others that it is beneficial. Beyond this, however, if the acidity of the rock being milled varies very much, as is frequently the case, the regulation of the amount to be added becomes rather difficult and auxiliary feeds become necessary.

For the second method, using an automatic feed, which is the one more generally adopted, many contrivances have been used which are far too numerous to mention, the purpose of each being the same—viz., to deliver a continuous stream of finely-ground lime into the launder, a minimum of attention being required.

The quantity of lime to be added will vary according to

the standard necessary to maintain to ensure settlement, which is usually about 0.01 per cent. of alkali, as expressed in terms of caustic soda for mill-water, and about double this for the solutions. The variation of the standards on the different mines is due to either the nature of the slimes themselves or the varying settling capacity of the plants, or both. On one mine the slimes will settle in the ordinary water, the probable cause being the mine water, which is very acid, and that they are already in a coagulated condition, and so settle readily; while on another mine where the settling capacity is limited it is necessary to maintain the mill water at a very high point of alkalinity. From this it will be seen that no rule can really be laid down in the matter.

Tests are made at frequent intervals of the alkalinity of both the water and the solution, to prevent loss of time, etc., through non-settlement.

In filling the collecting tanks the slime pulp is in some cases passed over a spitzkasten to eliminate the major portion of the water, but in others it is led direct to the collecting tanks, which in this case are fitted with overflow rims and launders round the top of the tanks; these are connected with piping, which conveys the clear water to either the dam or the pump direct. The launders conveying the pulp to the collecting tanks usually terminate in a vertical chute in the centre of the tank, the end being two or three inches below the level of the overflow; this is found to give the best results in preventing the slimes from overflowing with the water towards the end of the filling of the charge, as it causes a minimum of disturbance.

When the tank has received its charge (usually a quarter of its depth) the pulp stream is turned into another tank and the full one allowed to settle, when the water is decanted off, and the charge is ready for treatment. Here it may be well to mention that the last stage of settlement is marked by a peculiar appearance on the surface of the settled slimes, as of a series of small eruptions, which act as a guide in determining when it is ready for further operations.

The operations incurred in slimes treatment consist of first getting the gold into solution, and subsequently washing the solution out of the slimes. These are effected by a series of transfers, the number of which is determined by the richness of the material treated. For all ordinary cases where the slimes assay under 3 dwts. per ton, two transfers before sending away as residues are sufficient to give an extraction of, say, 75 per cent. from ordinary clean current slimes; if the value be above this, it may be found advisable and payable to give a third treatment.

The operation of transferring is carried out in the following manner:—

A hose with nozzle is attached to the solution service, and

the nozzle end is placed in the discharge hole in the bottom of the tank, the suction of the solution pump is opened to take solution from wherever desired, and the pump started; at the same time the discharge service is opened up into the sludge pump, the delivery of which is opened on to that particular tank to which it is desired to transfer. The primary object in putting the nozzle right in the hole is to thin down the sludge so as not to block up the pipes, and the solution should be started so as to avoid a rush of the sludge into the discharge pipe; all the connections are made so as to allow of the two pumps to take solution or sludge from wherever desired, and in the case of the solution it may be either taken from the sumps or from any of the tanks that have been settled, if it is part of the treatment. There is no particular difficulty in this operation, though it is rather difficult to make the matter clear in writing. Sometimes there is a little difficulty in getting it started if there has been any carelessness beforehand, and the pipes are at all blocked with sludge from a previous operation, or if the valve has not been properly closed, but this is remedied by an arrangement by which it is possible to pump solution through the sludge pump and up the discharge pipe. Once started, and the solution regulated, which is purely a matter of experience, the operation will go on with very little attention until nearly the whole of the tank is transferred, then the hose is lifted, and the balance can be washed down clean by the force of the jet issuing from the nozzle. When this is completed the suction of the sludge pump is closed off from that tank and opened on to the tank to which the charge has been transferred, by which means it is circulated by being drawn off at the bottom and delivered in again at the top. This circulation is kept up for as long as may be convenient or necessary according to the requirements of the treatment, generally about two hours.

The primary object in this operation is to get the slimes into contact with as much solution as possible, whether it be performed with the object of dissolving the gold or washing it out; for this reason it is found advisable to pump a quantity of solution into the tank to which transfer is to be made before pumping in any sludge. If circumstances warrant it, the whole of the solution can be first put in and drawn off through the decanter service for use through the solution pump to the hose in transferring a charge. In any case this should generally have to be done towards the finish of the transfer, so as to have the sludge thinned down as far as possible by using as much solution in ratio to settled slimes as possible.

Ordinarily the solution contains sufficient oxygen to perform its part in the dissolving of gold during its passage through the pump and subsequent circulation, but as the

sludge is generally well charged with sulphides, organic matter, or other compounds that require oxidation, it has been found advisable to use additional air in the pumps. Caldecott used perforated pipes in the tanks for this purpose, which Durant improved by using a snifter valve, bringing it into operation by partially closing a valve on the suction pipe, but this was found to detract from the efficiency of the pump, and so a jet of compressed air in the delivery pipe has been substituted in most of the plants with benefit, and found to accelerate the solution of the gold very considerably and to sweeten the solution efficiently. This auxiliary is not always necessary, but its continuous use is of little cost, and is often indispensable, while there is no easy means at present of first determining whether or how much oxidation is required.

After circulation, the charge is allowed to settle and the solution decanted off, and as the subsequent washing is a matter of dilution only, the solution should be drained off as completely as possible. In actual practice it is useful to take off the last inch or so with the pump and put it into another tank, by which means it is possible to take off a good deal more than would otherwise be the case, and as this last portion is a fairly thick sludge, the filters would be clogged up very quickly.

The second treatment of the slimes being merely a wash by dilution, is performed in exactly the same way as the first treatment, as is also the final discharge to the residue dam, except that in the latter case it is not essential to study the thinning down of the sludge, which operation is performed with as little water as can be used in the pump, the main object being to get it out quickly.

The general arrangement of the whole treatment will, of course, differ in various works, but the usual plan is to send all solutions from the first treatment to the filters, which also act as a storage and allow of a regular stream to be passed through the precipitation boxes to the sumps; this same sump solution is used to transfer the settled and decanted charge to the second treatment tanks, and thus becomes second treatment solution; this is again used direct from the tank to transfer the untreated slimes in the collecting tanks to the first treatment tanks, and when settled it is decanted to the filters. Thus, to recapitulate, from the first row of collecting tanks it is transferred to the first treatment row with second treatment solution (decantings called first treatment solution). From here it is transferred to the second treatment row with sump solution (decantings called second solution, and used for the transfer of the untreated charge to the first treatment row). From here it is sent to the residue dam with water.

This scheme is generally used for the treatment of the poorer slimes; it also has the advantage of making less solution pass through the filters and precipitation boxes; it thus

effects a small saving in plant, but it has the disadvantage of slightly enriching the solution left in the residues before sending them to the dam, so that in other plants where the slimes are richer, the decantings from both treatments are best sent to the filters, and sump solution used in all cases for transferring; this will have the effect of producing a slightly higher percentage of extraction. For much richer slimes the number of washings can be extended to any degree that is found payable to do so, and in direct ratio will effect the extraction provided that the complete solution of the gold is effected in the first treatment.

All solutions going to the precipitation boxes are first passed through the filter vats; these are simply steel tanks fitted with a filter mat similar to the leaching tanks, except that in these the distance underneath is very much greater, and that they have about two or three feet of clean sand placed upon it to arrest all solid matter. This has been found to be a necessary operation, as otherwise there would be a large deposit of practically worthless matter in the precipitation boxes. This would primarily form a coating on the zinc, and so act detrimentally to its efficiency, besides adding largely to the amount to be smelted subsequent to the clean-up, and thus causing an extra expenditure in fuel and fluxes in that operation. It is found advisable to clean out these filters, say every month, which simply means that the filter is drained dry prior to scraping away the accumulation of mud that has collected on the surface of the sand.

The precipitation of gold from slimes solution is simple enough, and consists of using zinc shavings in the usual form of box. Two modifications of the system used for sands and concentrates solution are, however, necessary, namely:—

1. Coating the shavings with metallic lead by dipping them into lead acetate solution.

2. Adding a stream of fresh cyanide solution to the box while it is in operation.

The details of the process, however, require some care and attention, for haphazard work and a want of experience and knowledge of the necessary conditions will be followed by poor results, as actually happened on some of the plants, when first tried.

The first detail to be considered will be the starting of the box, which may be for most purposes of the same construction as that ordinarily used. This is, of course, first cleaned out and the screen supports placed in position.

A bath of lead acetate solution is made up in a vessel such as a shallow tub, which will allow of the easy handling of the zinc shavings. The strength of this solution should be about 2 per cent., but this is not very material, as each man will eventually adopt his own way of arranging such details; but as a matter of information it may be said that if the solution be



much weaker the operation of coating the zinc will take up a longer time, whereas on the other hand, if used much stronger the coating will be more rapid, but there is a liability for the deposit to be in excess, and take a nebulous form, which is easily detached. This, apart from a waste of acetate of lead, should be avoided, as a thin, hard coating is found to act best and last the longest in the box. As the bath becomes weakened by each successive coating of fresh shavings, it will require the addition of more lead acetate to maintain the standard adopted.

This coated zinc is carefully and lightly packed in the compartments of the box with due regard to the avoidance of channelling, and as each compartment is filled the solution is turned into the box to avoid exposing the zinc to the air for too long a time; the reason for this is that the zinc so exposed becomes heated and rapidly oxidises, and therefore deteriorates; this is probably through the electrolysis of the moisture adhering to the shavings.

The period of efficiency of this process is limited. In some instances an efficiency of over 90 per cent. has been maintained for 30 days: this is, however, unusual, but there is no difficulty in maintaining it for fully half this period. In a general way, however, cyanide works are cleaned up every 10 days, and it is found convenient to transfer all the zinc to the sands precipitation boxes to replace that which has been decomposed, and to use fresh coated zinc for the slimes precipitation.

So far as is at present known, the conditions which influence the precipitation exist in the solutions or the physical condition of the zinc; usually the one governs the other. The exceptions are as before mentioned in regard to channelling and unsuitable coating of the zinc, to which might be added too large a stream in ratio to the amount of zinc; this, roughly stated, should be in the proportion of one ton of solution per hour for every 100 lbs. of zinc present. In some cases less than this will work well, and in others more will be required, but not to any great extent.

The foregoing can only be given as an outline of the process of the treatment of slimes, as the actual practice will depend so much upon the existing conditions, and modifications will have to be made accordingly, as, for instance, in the degree to which it is found payable to prolong the treatment, or the presence of deleterious matter in the material treated. Finally, it may be said that the profits of slimes plants depend a good deal upon the magnitude of their operations, and therefore inattention to details results in proportionate losses.

The slimes when treated have to be disposed of, and this subject, though of great importance in the future, is hardly a fit subject for the present treatise. Owing to their being in the form of a thin sludge, they are at present pumped into dams, the construction and up-keep of which form a very important

item of the costs. Experiments are being made to ascertain what will ultimately be the cheapest system to be adopted, as is also the subject of recovering the gold from the water with which it is pumped out of the tanks; this, acting as an extra wash, will often contain as much as from 4 to 6 grains per ton, but so far the experiments have reached no conclusive stage.

The process of cleaning up and recovering the gold has been much modified of late by the adoption of acid treatment, filter-presses, and the use of clay-lined crucibles in reverberatory furnaces, and latest of all the process known as the Tavener method, which consists of melting with litharge and a reducing agent, thus getting the gold into lead, which is afterwards cupelled, giving a bullion which is practically pure gold and silver.

The systems adopted on the different plants are various, and would, if given in detail, entail too much explanation; it is therefore proposed to give merely an outline of one of the most modern.

The strong solution boxes are first taken in hand, the flow stopped, and some of the solution syphoned off. All the zinc in the top compartments is usually decomposed and unfit for further use; it is therefore taken at once to the acid tub. The cyanide manager generally uses his discretion as to what zinc is returned to the boxes or sent to the acid tubs, being guided throughout the plant by the appearance of the zinc in the matter of richness or suitability for further use. The filter press having been prepared with a suitable number of leaves or frames, is started, and the suction hose put in to drain the balance of the solution, whilst the next compartment is similarly treated. When as much as is possible has been pumped out, the suction hose is transferred to the next compartment, and the solid matter at the bottom of the compartment is either baled or shovelled out and sent to the acid tub, being finally sponged out clean. By this means, when the lower compartments are reached a place will be ready for the zinc, which has to be returned.

All the boxes are proceeded with in like manner, the returned zinc being placed in whichever box is convenient; usually that from the medium goes to the strong, and that from the weak to the medium, while that from the slimes plant goes to the weak. Fresh zinc is supplied to fill up the whole plant where needed.

When this operation is finished the filter press is also emptied into the acid tub, which will then contain the whole of the clean-up.

These acid tubs should have had acid and water in previously, so that when the clean-up is put in, the action of dissolving out the zinc commences at once, and no time is lost; fresh acid is added from time to time as necessary, and the



whole stirred up, cautiously at first to avoid bubbling over, and very thoroughly at the end to ensure all the zinc being dissolved. After settling, the clear liquor is decanted off through plug holes in the side of the tub into the lower one, and again filled up, this time with hot water, being again thoroughly stirred. This is repeated several times to wash out all the soluble salts. These washings are drawn off through the filter press, which is again rigged up with the necessary number of leaves, and when the washing is complete, all the gold slimes are washed into the lower tub, now empty, and carefully drawn off into the filter press, being stirred up the while with sufficient water to form a thin mud so that the press is filled evenly. When all is in the press it receives a final washing, and then the pump is continued on air for some time to dry as much as possible.

If the right number of leaves has been used the resulting cakes of gold slimes should be comparatively dry and hard, and so easy to handle.

These cakes are placed in iron trays fitting into the drying furnace, and broken up slightly to facilitate this. With the use of clay-lined crucibles it is not necessary to roast, though by so doing the resulting bullion is a little finer.

The dry slime is broken up fairly small and mixed with flux for smelting. The constituents of this flux will vary, but generally it may be said that for every hundred pounds of dried slimes the proportions will be: Anhydrous silicate of soda, 40 lbs.; fused borax, 40 lbs.; and peroxide of manganese, 7 lbs.; the latter is the most varying element, being used to oxidise the lead, etc., present.

On most of the larger works a reverberatory furnace is used for smelting, owing to the large nature of the operations, besides which it is cheaper in fuel and fluxes. Each charge takes about two hours in the furnace, the pots are handled rapidly and poured into one common mould, one on top of the other: a launder at the top of the mould conveys the major portion of the slag outside the building, where it falls into water, and, becoming granulated, saves time in the subsequent grinding up to recover the fine beads held in the slag in suspension. The advantage of this system, besides cheaper and quicker working than the old Cornish furnace, is the easier handling, with less heat and discomfort to the workmen, while a greater heat is obtainable in the furnace, which renders the slag more fluid, and by pouring one charge on top of the other, beads held in suspension are carried down, and the slags produced are far less in value than by the old method. The resulting bullion is finer also, and commands a higher price by the use of the oxidising flux in the clay-lined crucible.

It is a source of great satisfaction to the metallurgists of the Rand that slimes of 2 dwts. in value are successfully treated at a profit of over 4s. per ton. This has been accom-

plished by the joint labour of the engineer, and the chemist and metallurgist, and last but not least the courage of the capitalist, who has not hesitated to put a half-a-million of money to develop a mine with the necessary surface equipment before the first ounce of gold can be obtained. Incidentally I may mention that one of the last slimes plants that have been erected cost nearly £40,000, but as a profit of about £3,000 per month has been obtained, you will agree that it is a very good investment.

I trust that these few remarks will be of some assistance to you during your forthcoming visit to the mines, when you will see the whole of the process in active operation.

### 3. THE CYANIDE PROCESS FROM THE STANDPOINT OF MODERN CHEMISTRY.

BY JAMES MOIR, D.Sc., M.A., F.C.S.

Although it is now seventeen years since Arrhenius first promulgated the ionic theory, it is only within the last half-dozen years that it has made progress towards universal acceptance among chemists and physicists. The chief cause of the opposition—both scientific and unreasoning—with which it has met, is the difficulty of clearly conceiving its fundamental idea, viz., that elements carrying opposite electric charges (such as sodium and chlorine) can exist side by side in solutions, being kept apart merely by being admixed with a large excess of neutral molecules of high dielectric-constant such as water. This difficulty is a real one, and it is only by dint of the general impression of neatness and consistency which is produced by the explanations founded on the ionic theory, that the theory itself has now reached the position of holding sway over the whole domain of inorganic chemistry—at least as a reliable working hypothesis, which fits together into one system a number of facts which would otherwise remain discrete and inexplicable.

With regard to the theory itself, it will be unnecessary for me to say much in the way of description, especially on the mathematical side, since that has already been done in this country by Professor v. Oettingen, and is readily available in the pages of the Journal of the Chemical and Metallurgical Society for 1899. As the Professor, however, confined himself to the theoretical side of the question, I have thought that it might be serviceable to apply the theory to the practical subject of the cyanide process of gold extraction, especially as I find that it throws light on a variety of phenomena which are otherwise puzzling.

The ionic theory (or theory of electrolytic dissociation) has been invented to explain the following sets of facts:—

(1) Solutions of salts, dilute acids and dilute bases behave towards reagents as if they were mixtures, whereas the other classes of soluble substances do not. Thus a solution of common salt gives a precipitate of silver chloride when added to silver nitrate solution, whereas a solution of sodium chloracetate does not, although it contains chlorine also. This must mean that the chlorine of a salt solution is isolated or separate from the other substances present, and free to react with silver, whereas in the chloracetate, it is bound up with part of the molecule and cannot be got at by the silver. Salt solution contains  $\text{Na}^+$  and  $\text{Cl}^-$  ions,\* but the chloracetate gives only  $\text{Na}^+$  and  $\text{CH}_3\text{ClCOO}^-$  ions, and no  $\text{Cl}^-$  ions.

Similarly  $\text{KClO}_3$  solution contains only  $\text{K}^+$  and  $\text{ClO}_3^-$  ions and no  $\text{Cl}^-$  ions and therefore is not precipitated by silver nitrate. Again all ordinary silver salts are precipitated by chlorides, but  $\text{KAgCy}_2$  is not, because it contains practically no  $\text{Ag}^+$  ions, only  $\text{K}^+$  and  $\text{AgCy}_2^-$  ions. To take another example, if we make equivalent

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\* The dots (·) and dashes (') represent the positive and negative charges respectively.

solutions of all the soluble permanganates they look exactly alike to the eye and through the spectroscope. This means that they all contain the same free, coloured ions  $\text{Mn O}_4^-$  in the same amount (though the amounts of metal present vary according to their atomic weights). Similarly the ultra-violet spectra of all the nitrates (in equivalent solution) show a series of bands identical in each case, caused by the free  $\text{NO}_3^-$  ion.

In the second place, all dilute acids have certain properties in common, viz., sour taste, power of reddening litmus, and liberating hydrogen when treated with such metals as magnesium. Now hydrogen is the only thing common to the acids and therefore the acidic functions have long been ascribed to hydrogen. However as these properties are not possessed either by gaseous hydrogen ( $\text{H}_2$ ) or by hydrogen in other soluble compounds such as sugar, urea, hydrogen peroxide, etc., the hydrogen in acids must be different from both molecular hydrogen and combined atomic hydrogen. The fact that the difference in the properties of acids is one of degree and not of kind, shows that the hydrogen is separate from the rest of the molecule and exhibits its own reactions exactly to the degree to which it is free or dissociated. Speaking shortly, the acidic properties are the properties of the positively-charged hydrogen ion ( $\text{H}^+$ ); an acid is strong if it is well dissociated and is weak if only slightly dissociated into  $\text{H}^+$  ions. Strong acids are,  $\text{HCl}$ ,  $\text{HBr}$ ,  $\text{HI}$ ,  $\text{HNO}_3$ ,  $\text{HClO}_3$ ,  $\text{HBrO}_3$ ,  $\text{HIO}_3$ ,  $\text{HClO}_4$ ,  $\text{HSCy}$ ; medium are,  $\text{H}_2\text{SO}_4$ ,  $\text{H}_2\text{C}_2\text{O}_4$ ,  $\text{H}_3\text{PO}_4$ ,  $\text{HF}$ ; weak,  $\text{C}_2\text{H}_4\text{O}_2$ ,  $\text{HOC}_2\text{H}_5$ ,  $\text{H}_2\text{S}$ ,  $\text{H}_2\text{SO}_3$ ,  $\text{H}_2\text{CO}_3$ ,  $\text{H}_3\text{BO}_3$ ,  $\text{HCN}$ ,  $\text{C}_6\text{H}_5\text{OH}$ . Speaking generally, the properties of a salt solution are the sum of the properties of its ions: the principle in ordinary analysis of looking for acids and bases independently of one another is nothing else than a recognition that ionisation has occurred. On the contrary the detection of organic substances has to be done *individually*; for example there is no group-reagent for the methyl-group, simply because it does not ionise.

Thirdly, it is found that solutions of salts, acids and bases conduct the electric current with decomposition, whereas solutions of other soluble substances are non-conductors. It is only in the state of solution that these substances are conductors, *e.g.*, anhydrous  $\text{HCl}$  (liquefied) is a non-conductor, and does not affect litmus or metals, but when added to water much heat is evolved and the solution reacts acid and conducts the current easily with evolution of hydrogen and chlorine at the electrodes. The profound nature of the physical change is shown by the rise of the boiling point from  $-102^\circ\text{C}$  to over  $+100^\circ\text{C}$ . The conductivity of salts (electrolytes) differs from that of metals in being accompanied and caused by an actual transference of matter, viz., the ions into which the electrolyte separates when dissolved, these ions carrying each a definite charge of  $-$  or  $+$  electricity. The passage of the current is simply the migration or wandering of these charged particles through the solution in obedience to the attraction exercised on them by the electrodes.

Thus the plus electrode (anode) attracts all the minus ions (say  $\text{Cl}^-$ ) and repels all the plus ions (say  $\text{H}^+$ ), whilst the negative electrode attracts the positive  $\text{H}^+$  ions which have been repelled from

the other side and repels the negative ions to the other electrode which attracts them. (Fig. I.)

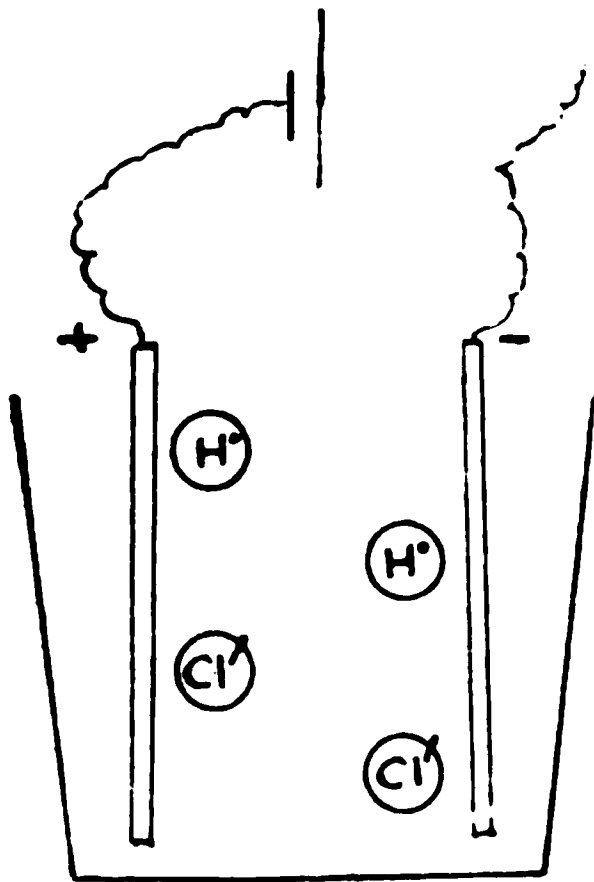
The ions therefore move in opposite directions through the liquid until they meet the electrodes which being oppositely charged to them, remove their charges, and the ions are left free to exercise their chemical affinity and combine with one another or with other ions that may be present, to form ordinary molecules. In this discharged but uncombined condition they are in the "nascent state" to use the older terminology, and are very reactive, since there is no force to oppose their chemical affinity.

The difference between an element in the ionic state and one in the nascent or in the ordinary molecular condition is fundamental in character. They are as totally different in their properties as the allotropic forms of phosphorus or as oxygen and ozone; in fact the ionic condition is most simply understood as a specially reactive allotropic form of the element. Nowadays allotropy itself is generally explained by differences in the number or arrangement of the atoms in the molecule, exactly like isomerism in more complicated substances, and according to the ionic theory every element can assume different allotropic forms. Thus hydrogen may be (1)  $H_2$  (gas), (2)  $H-$  (nascent), or (3)  $H\cdot$  (ion). Again Iodine may be (1)  $I-I$  (vapour at low temperature) (2)  $I-$  (nascent or vapour at very high temperature)

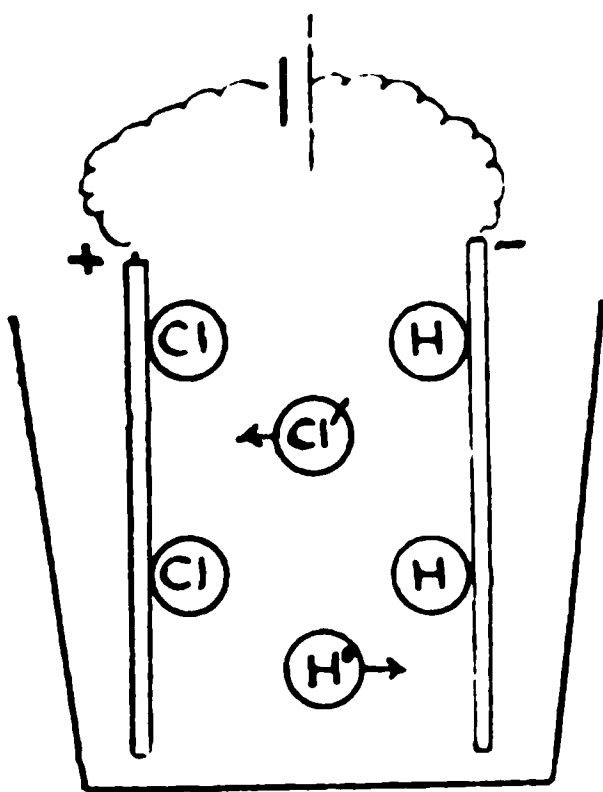
(3)  $I'-(\text{ion of iodides})$  (4)  $-I \begin{array}{c} I' \\ \parallel \\ I \end{array}$  (ion of tri-iodides). Again nitrogen may be (1)  $N \equiv N$  (gas), (2)  $-N \begin{array}{c} N \\ \parallel \\ N \end{array}$  (ion of hydrazoates). The same

applies to compound radicles or groups, thus we have the isomers  $OH\cdot$  and  $(OH)_2$  or  $H-O-O-H$ , the first being the radicle of all the hydroxides and the second ordinary hydrogen peroxide; another example is  $Cy\cdot$  (the anion of the cyanides) and its isomer  $Cy_2$  or  $NC-CN$ , or ordinary cyanogen. These isomers have the most widely different properties, hence it is no longer wonderful that the sodium ion does not attack water: it is totally different from metallic sodium.

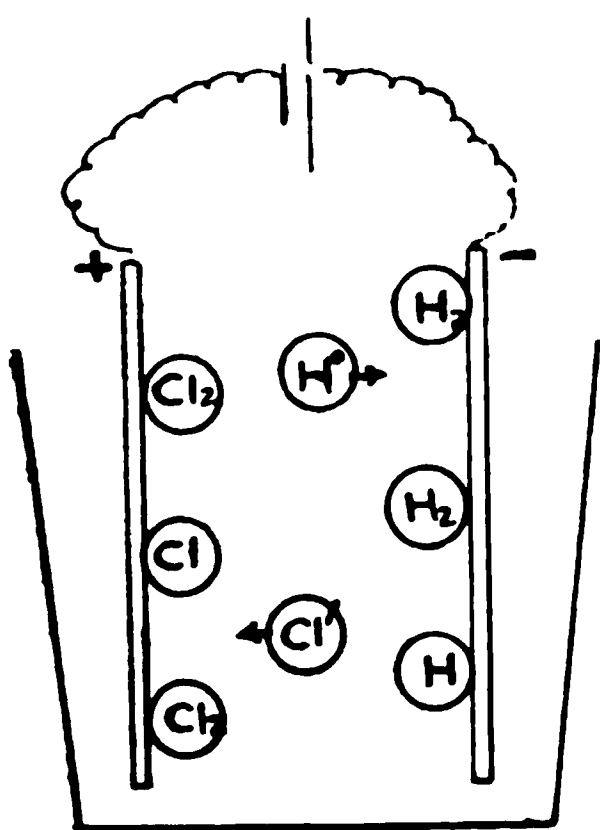
There is one more point to be elucidated before applying all this to the cyanide process, and that is, that dissociation is frequently very incomplete, for example in water, and many of the acids. Now since conductivity depends on the actual carriage of electric charges by the ions, it follows that bad conductors contain few ions and are therefore only slightly dissociated. For example  $HCN$  is a very poor conductor and is therefore scarcely dissociated at all. Its solution therefore contains very few  $H\cdot$  ions, and it therefore should not exhibit the reactions of  $H\cdot$  ions. Now these are the reactions of an acid, and we infer that  $HCN$  is a very weak acid, which is in fact the case. By measurements of the conductivity of pure acids we can therefore arrange them in order of dissociation, which is therefore the order of strength. For example  $HCN$  is thus found to be 15.8 times weaker than carbonic acid and hence its salts are very completely decomposed by atmospheric  $CO_2$ .



(a.) *Before passing current. Only  $H^+$  and  $Cl^-$  ions are present and are moving in all directions.*



(b.) *Beginning of current. Ions move in opposite directions; nascent  $H$  and  $Cl$  are formed at electrodes.*



(c.) *During current. Separation of gaseous  $H_2$  and  $Cl_2$ ; nascent  $H$  and  $Cl$  at electrodes; ions moving in opposite directions.*

FIG. 1.

Again it follows that if highly-dissociated solutions are mixed so as to have the ions of a slightly-dissociated substance present together, these ions must re-combine. The best known case is that of water; if an acid and a base, containing respectively  $H^+$  and  $OH^-$  ions, be mixed, these ions must combine until their number is reduced to the quantity ordinarily present in water ( $\cdot000011\%$ ), the metal and anion of the acid remaining unchanged to form the salt which results on evaporation. The process of neutralization is thus independent of the nature of the base or the acid (if strong), and in point of fact it is found that the same amount of heat is liberated, whatever the base or (strong) acid may be. This heat is the amount produced by the reaction  $H^+ + OH^- = H_2O + 137$  cal. per litre. All analytical reactions (titrations, formation of precipitates, etc.) depend on differences of dissociation and solubility of the substances employed: they are reactions of ions, metals and complexes, and unless a particular group is dissociated, its constituents are not detected. Thus the substance obtained by dissolving gold in cyanide,  $K Au Cy_2$ , when dissolved in water dissociates into  $K^+$  and  $Au Cy_2^-$ , and consequently gives the reactions of potassium and of the aurocyanide group, but does not give the reactions of gold or ordinary cyanides, unless it is treated with violent reagents which destroy the  $Au Cy_2^-$  group. In the same way, potassium ferrocyanide does not react for iron and is non-poisonous.

In the case of salts the dissociation is practically complete, and if one recollects the few exceptions, it is practically safe to assume that nothing but ions is present. The important conclusion is that when different salt solutions are mixed, the product is the same however the ions were arranged in the original solids. For example a mixture of equivalent solutions of  $NaCl$ ,  $KI$ , and  $Ca(NO_3)_2$  cannot be distinguished in any way physical or chemical from a mixture of  $KCl$ ,  $NaI$ , and  $Ca(NO_3)_2$  or of  $NaNO_3$ ,  $KCl$  and  $CaI_2$  or of any of the other three possible combinations of the six ions. If on the other hand any difference arises on mixing salt solutions, there must be one among the possible substances, the ionisation of which is less than that of the others. This substance then forms from its ions and if its amount exceeds the solubility of the substance, it separates as a precipitate and the temperature rises from the combination of the ionic charges. Conversely the redissolving of a precipitate simply consists in aiding it to ionise.

There are still many points of theoretical interest such as osmotic pressure, depression of freezing point, etc., required to prove the validity of the ionic theory, but I do not propose to refer to these. Those who are interested may be referred to the excellent exposition of the theory in Watts' Dictionary of Chemistry, IV., 183, where the quantitative data which prove the theory may be inspected and will convince most people that they are not due to mere coincidence.

Besides the ionic theory another application of physical chemistry—the law of mass action—has come to play a most important part in modern chemistry. This law is simply a statement in mathematical form of the fact that the degree to which a substance reacts is propor-



tional to the amount of it present. Combining this with the ionic theory we learn that the activity of a substance depends on the concentration of its ions (*i.e.*, the number present per litre). If we take any chemical equation the activity of each constituent on the left side is proportional to its concentration, therefore the tendency for the reaction to go in the sense of the reaction is measured by the product of the concentration of the substances on the left side minus the product of the concentrations of the substances on the right-hand side. In equilibrium this tendency is zero, and the two sides are equal. Expressed algebraically this is  $C_1C_2 = K C_3C_4$  if there are two substances on each side. The constant  $K$  measures the final stage of the reaction. Take for example the dissociation of water,  $H_2O = H^+ + OH^-$ ; the algebraical equation is  $(H_2O) = K(H^+)(OH^-)$  if we denote by bracketted groups the concentration of the substance within the bracket. Now, in the case of water, the dissociation is known from the conductivity to be extremely small; the quantity of un-dissociated water in a litre is

therefore practically constant; therefore  $(H^+) \times (OH^-) = \frac{(H_2O)}{(K)} = \text{con-}$

stant. Therefore in any aqueous liquid  $H^+$  and  $OH^-$  ions are always present, and in such numbers that their product is constant. The value of the constant is  $0.7 \div 10^{-14}$  at  $20^\circ$  and  $1.1 \div 10^{-14}$  at  $25^\circ$ , and  $6.2 \div 10^{-14}$  at  $50^\circ\text{C}$ , increasing rapidly with temperature.

In pure water the  $H^+$  and  $OH^-$  ions are of course equal in number, therefore  $(H^+) \times (OH^-) = (H^+)^2$  therefore  $H^+ = OH^- = 10^{-7}$  (or one each of the ions to ten millions of water). Now if we add an alkali to water we greatly increase the number of  $OH^-$  ions, therefore the number of  $H^+$  ions must greatly diminish in order to keep their product fixed, but it is not possible to entirely remove the  $H^+$  ions. Thus in normal KOH solution at  $25^\circ$  the concentration of  $OH^-$  is  $= 1$  and since  $(H^+) \times (OH^-) = 1.1 \times 10^{-14}$  at  $25^\circ$  therefore  $H^+ = 1.1 \times 10^{-14}$ , *i.e.*, about one ten-millionth of its concentration in water. We can usefully apply these facts to the hydrolysis of potassium cyanide by water. When a solution of potassium cyanide is made it is found to react alkaline, and it also smells of hydrocyanic acid, even if the water has been freed from carbonic acid. This is due to the fact that hydrocyanic acid is an extremely weak acid, *i.e.*, one which is only slightly dissociated into ions, whilst its soluble salts are, of course, well dissociated. The solution contains  $K^+$  and  $Cy^-$  ions as well as the ions of water  $H^+$  and  $OH^-$ , and since HCN, like water, is only slightly dissociated it tends to be formed when its ions  $H^+$  and  $Cy^-$  meet in solution, just as water is produced when  $H^+$  and  $OH^-$  meet together. Now when  $OH^-$  and  $Cy^-$  together meet with  $H^+$  they compete for it according to their degree of dissociation, and HCN being the more dissociated, is produced in the lesser degree. In consequence a cyanide solution consists mainly of water with potassium and cyanogen ions, but contains in addition to these, free  $OH^-$  ions (which cause its alkalinity), and un-dissociated HCN, which can be distilled out of the solution. The amount of hydrolysis is about 1% in a 0.5% KCy solution at ordinary temperatures and the hydrolysis varies as the square root of the strength of the



solution. Now it is customary to add caustic alkali to cyanide solutions, and we can calculate its effect. From the two chemical equations,  $H \cdot + OH' = H_2O$  and  $H \cdot + Cy' = HCN$ , we have two concentration-equations from the law of mass action, viz.,  $(H \cdot) \times (OH') = 1.1 \times 10^{-14}$ ,  $(H \cdot) \times (Cy') = k \times (HCN) = 13 \times 10^{-10}(HCN)$ . We eliminate  $(H \cdot)$  and find since  $(Cy')$  in decinormal solution = 0.1,

$$(OH') \times (HCN) = \frac{11 \times 10^{-16}}{13 \times 10^{-10}} = 10^{-6} \text{ roughly—that is, the product of}$$

$OH'$  ions and free HCN is constant, and since they are equal in pure KCy solution, both  $(OH')$  and  $(HCN) = \sqrt{10^{-6}} = .001$  or 1% of the cyanide present. So, if we double the  $OH'$  ions we halve the free HCN, or, in other words, to halve the loss of available cyanide (*i.e.*,  $Cy'$  ions) due to hydrolysis, we must double the alkalinity. In a decinormal cyanide solution at 30° C. this is 1.12 % of the KCN, so that we must add alkali equal to this, viz.,  $.00112 \times 56$  (molecular wt. of KOH) = .0627 gram KOH per litre.

**TITRATION OF CYANIDE SOLUTIONS.**—We have seen that a pure cyanide solution contains seven individual substances, viz., un-dissociated KCN, water, and HCN, and dissociated  $K'$ ,  $H'$ ,  $OH'$  and  $Cy'$ . Of these only the last is of value for dissolving gold, and the titration process must be arranged so as to determine cyanogen as ion only. The most familiar method is the use of standard silver solution. From the ordinary equation  $2KCy + AgNO_3 = KAgCy_2 + KNO_3$  we get the ionic equation  $Ag' + 2Cy' = AgCy'_2$ . It should be noted that every ionic equation must have the algebraic sum of the ionic charges equal, as well as the elements involved. It does not matter what silver salt is used. It should also be noted that although the un-dissociated KCN is not titrated at once, as soon as some of the  $Cy'$  ions have been removed by the silver the equilibrium existing between KCN and its ions is disturbed, and therefore more KCN is dissociated until it is restored; this goes on until the whole of the KCN is dissociated and is titrated. On the other hand, the equilibrium between the  $OH'$  and the free HCN is not disturbed, and consequently the latter, not being ionised, is not titrated, and as we know that the hydrolysis is about 1% in a solution of  $\frac{1}{2}$  % KCy, we see that the titration gives only 99 % of the total cyanide dissolved. Nevertheless the titration is correct for leaching purposes, since this 99 % is all that is available for dissolving gold. Addition of alkali, as already mentioned, makes more available. In view of all these facts, the custom of recording results in terms of KCy is simply stupid, as is also the prejudice against using sodium cyanide. It is true that the latter salt is frequently impure, but this is simply because manufacturers are encouraged to send out an article containing only 76 % of sodium cyanide, simply because this figure works out at 100 % KCy; there remains 24 % for impurities, none of which are valuable enough to be paid for as cyanide. It ought to be easy enough to put pressure on manufacturers to raise the  $Cy'$  content from 40 % (its present amount) to 50 % since  $Cy'$  in pure NaCN is 53 %.

The other two processes for titrating cyanides are very interesting from the ionic point of view.

The first consists of titrating with  $\frac{N}{10}$  iodine until it is no longer used up, the equation being  $\text{KCN} + \text{I}_2 = \text{KI} + \text{ICN}$ . The *rationale* of the proceeding is that cyanogen iodide is not dissociated (for example it gives no precipitate with  $\text{AgNO}_3$ ). The ionic equation is therefore  $\text{Cy}' + \text{I}_2 = \text{I}' + \text{CNI}$ , the negative charge moving from cyanogen to iodine. It is interesting to note that if the final solution is acidified, the reaction goes backward, iodine and  $\text{HCN}$  being regenerated, the equation in ionic form being  $\text{I}' + \text{CNI} + \text{H}^+ = \text{I}_2 + \text{HCN}$ . The other process uses  $\text{HgCl}_2$  solution and depends on the remarkable fact that  $\text{Hg}(\text{CN})_2$  is practically not ionised and does not give either the mercury or the cyanide reactions, and this is due to the fact that  $\text{Hg}^{++}$  and  $\text{Cy}'$  ions are practically absent from its solutions. The equation of titration is  $\text{HgCl}_2 + 2\text{KCN} = \text{Hg}(\text{CN})_2 + 2\text{KCl}$ , or in ionic form  $\text{Hg}^{++} + 2\text{Cy}' = \text{Hg}(\text{CN})_2$ .

Before dealing with the chemistry of the solution of gold, it will be necessary to say something about the destruction of cyanide by constituents of the ore, the air and the water with which it is used. We have seen that even pure air-free water causes a loss due to hydrolysis, the  $\text{HCN}$  formed being volatile. It may be removed from solution even by a current of indifferent gas, as occurs in aëration. A much greater cause of loss is the action of carbonic acid. This, we have seen, is nearly 16 times as strong an acid as  $\text{HCN}$ , and a cyanide solution is almost completely converted into  $\text{KHCO}_3$  by exposure to air for a long time. It is sometimes supposed that  $\text{K}_2\text{CO}_3$  is the product, but this is incorrect. I have done a number of experiments to test the action of carbonic acid. For example, I compared the cyanide-destroying powers of  $\text{HNO}_3$  and  $\text{H}_2\text{CO}_3$  as follows: 25cc. of  $\text{KC}_y$  solution were titrated and used 9.82cc's of  $N/10$  silver solution, but on mixing with 50cc. of  $\text{CO}_2$  - water (equal to 4.32cc. of  $N/10 \text{HCO}_3\text{H}$ ), the titration gave 8.67cc's of  $\text{AgNO}_3$ . On mixing the cyanide with 4.32cc's of  $N/10 \text{HNO}_3$ , the titration gave 8.75cc's of  $\text{AgNO}_3$ . Thus  $\text{H}_2\text{CO}_3$  caused a loss of  $11.8\%$  of the cyanide, as compared with  $13.3\%$  destruction by  $\text{HNO}_3$  in equivalent quantity. On doubling the quantity of  $\text{CO}_2$  the destruction of cyanide was  $25.8\%$ , whereas double the quantity of nitric acid caused a loss of cyanide =  $34\%$ . From this we see that although  $\text{H}_2\text{CO}_3$  is a very weak acid, it is so much stronger than  $\text{HCN}$  that it expels it from its salts almost as much as  $\text{HNO}_3$ , the type of a strong acid. It does not, however, effect  $\text{KAgCy}_2$  because the latter contains the ions  $\text{K}^+$  and  $\text{AgCy}'_2$  but not the ion  $\text{Cy}'$  to any appreciable extent. In the presence of potassium iodide, however,  $\text{CO}_2$  does cause precipitation from  $\text{KAgCy}_2$  solution.

Another source of loss of cyanide is the presence of acid salts in the ore. The action of free acid is so obvious that it need only be mentioned. The action of acid salts depends on their hydrolysis, leading to potential free acid; the effect on cyanide is here again due

to  $H^+$  ions, and these are formed when the base of the salt is a weak one. Just as cyanide, the salt of a weak acid, hydrolyses into undissociated acid and dissociated base, so does a salt of a weak base like ferric sulphate, hydrolyse into undissociated base and dissociated acid, e.g.  $Fe_2(SO_4)_3$  hydrolyses into  $Fe(OH)_3$  and  $H^+$  and  $SO_4^{''}$  ions. The action of  $Fe_2(SO_4)_3$  on cyanide is thus not directly  $Fe_2(SO_4)_3 + 6KCy + 6H_2O = 2Fe(OH)_3 + 6HCN + 3K_2SO_4$ , but is simply the ionic actions

$$\left\{ \begin{array}{l} 2Fe^{+++} + 6H^+ + 6(OH)^- = 2Fe(OH)_3 + 6H^+ \\ H^+ + Cy^- = HCN \end{array} \right\}$$

Another very deleterious ingredient of the same class is  $MgSO_4$  in the water, the reaction is  $Mg^{++} + 2OH^- + 2H^+ = Mg(OH)_2 + 2H^+$ .

The action of ferrous salts is different, for here the cyanide is not converted into HCN but into ferrocyanide. The reaction is simply  $Fe^{++} + 6Cy^- = FeCy_6^{--}$ .

To counteract all the foregoing causes of loss of cyanide it is customary to add caustic lime; this is fairly satisfactory but far from perfect. As we have seen, the hydrolysis is only slightly diminished by a considerable quantity of alkali, but on the other hand lime is a complete remedy for dissolved  $CO_2$ . For free acid and acid salts it is fairly satisfactory when pure but since the product  $CaSO_4$  has a distinct action on cyanide (owing to the fact that  $CaCy_2$  is more subject to hydrolysis than  $KCy$ ), it would be far preferable to use a mixture of lime and caustic soda. The practice of using crude lime containing much carbonate is very wasteful, since the carbonic acid produced is itself a "cyanicide." Even caustic alkali, however, is no protection against ferrous salts, since ferrous hydrate reacts with cyanide to form ferrocyanide. Again, ferrous hydrate is very deleterious to the cyanide process in another way, *viz.*, by possessing a strong affinity for dissolved oxygen. Thus the addition of lime to a gold ore containing ferrous sulphate will cause most of the dissolved oxygen of the water to disappear and the gold cannot therefore be extracted unless the solution is thoroughly re-aërated. The only other important cause of loss of cyanide is the presence of compounds of base metals. These act just like ferrous iron by forming complex anions with the  $Cy^-$ . Thus in the case of copper we have the formation of  $KCuCy_2$ . If the copper is present as cuprous salt, it is formed directly,  $Cu_2O + 4Cy^- + H_2O = 2CuCy_2^-$  (anion of potassium cuprosocyanide) +  $2OH^-$  (alkali). In the case of a cupric salt, free cyanogen is liberated in addition and the ionic equation is  $2Cu^{++} + 6Cy^- = 2CuCy_2^- + C_2N_2$ .

With regard to the subject of destruction of cyanide, I notice in our literature frequent references to an entity called "protective alkali" round which much discussion seems to have raged, with the confusion of thought usual when conflicting definitions of the subject of the discussions are in use. Now in the light of the ion-theory, "protective alkali" is nothing else than  $OH^-$  ions, for these are the only ions which are attacked before  $Cy^-$  ions when a substance of acidic character, (*viz.*, containing  $H^+$  ions) is present. There is no acid weaker than HCN (except phenol), hence  $KCy$  can only be protected by hydroxides. The protection afforded by normal sodium carbonate is simply due to its slight hydrolytic dissociation into

NaHCO<sub>3</sub> and NaOH (about 3% in  $\frac{N}{10}$  solution), but as soon as the

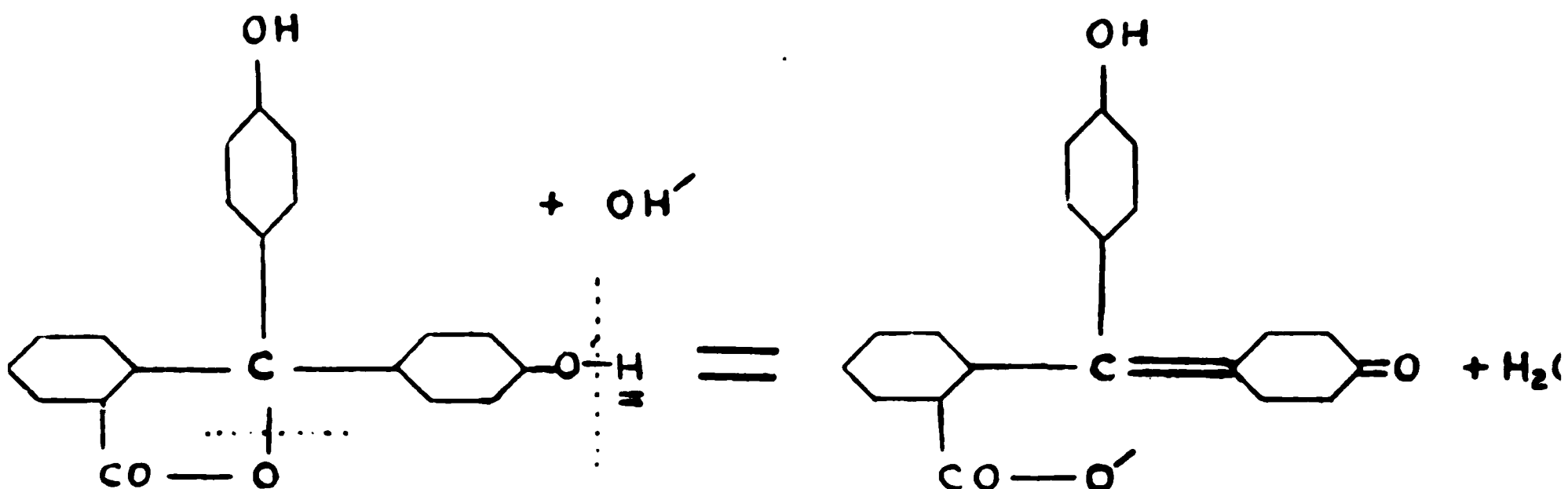
latter (or its OH' ions) is used up by a cyanide, more hydrolysis occurs and so on until all the NaOH (equal to half the original carbonate) has been utilised as a protector. Hence the definition that protective alkali is "all the hydroxides and half the alkaline carbonates present." The reactions are (1)  $\text{CO}_3'' + \text{H} \cdot + \text{OH}'$  (from water) =  $\text{CO}_3\text{H}' + \text{OH}'$  (2)

$\text{CO}_3\text{H}' + \text{OH}' + \text{H} \cdot$  (from the cyanide) =  $\text{CO}_3\text{H}' + \text{H}_2\text{O}$ . To be exact, the final stage is an equilibrium between H· and the two anions OH' and Cy' so that the protective action is really rather less than one half of the Na<sub>2</sub>CO<sub>3</sub> present. The OH' groups present in a cyanide solution are determined by Clennel's method, the principle of which consists in removing the Cy' groups with silver solution before titrating with acid. If the Cy' groups were not removed, they would constantly react with the water to form HCN and OH' as previously explained and we should determine the alkali corresponding to the KCy present as well as the protective alkali. The reactions are  $2\text{Cy}' + \text{OH}' + \text{Ag} \cdot = \text{AgCy}'_2 + \text{OH}'$ . Then on titrating with N/10 oxalic acid with phenolphthalein, we have  $\text{AgCy}'_2 + \text{OH}' + \text{H} \cdot = \text{AgCy}'_2 + \text{H}_2\text{O}$ . Phenolphthalein is a stronger acid than HCN which is the reason why it is not liberated from its red potassium derivative until practically all the KCy has been decomposed, but if the solution contains not KCy but KAgCy<sub>2</sub>, the phenolphthalein is liberated from its coloured salt as soon as all the OH' has been neutralized. If 100cc. of cyanide solution be taken, each cc. of N/10 oxalic or sulphuric acid corresponds to .004% NaOH, .0056% KOH, .0028% CaO, .0037% Ca(OH)<sub>2</sub>, or to .0017% OH'. In consequence of adherence to the older theories there is much confusion as to what terms alkalinity is reported in. It would be much clearer to report in terms of OH', the real cause of the alkalinity, to say nothing of its scientific accuracy. Some of you may be interested in the cause of the colour change on adding alkali to phenolphthalein. It has been shown by Armstrong that nearly all coloured organic compounds have a constitution analogous to quinone, namely a double-linked benzene ring. Phenolphthalein has the constitution (I.). Fig. 2.

When it meets with alkali, (*i.e.*, OH' groups), the linkage breaks at the dotted lines, and the anion of the red salt is formed, the underlined H is removed by the OH', and the negative charge of the OH' goes to the coloured anion, which has been formed.

The formula of the coloured ion, (with quinonoid linkage), is (II.) Conversely by adding an acid, (H· ions) to this compound the H· ion joins on to the quinone oxygen and the free bond of the other oxygen joins up to the central carbon, thus regenerating the original, electrically-neutral and colourless phenolphthalein.

Coming now to the actual process of gold extraction, we must remember that even a pure cyanide solution is a very complex thing, but nevertheless it is only the ionised cyanogen and the dissolved (but not ionised), oxygen which cause the solution of gold. Metallic gold is not ionised and has indeed only an extremely small tendency to



(I.)—Free Phenolphthalein (Colourless).

(II.)—Coloured ion of Salt.

FIG. 2.

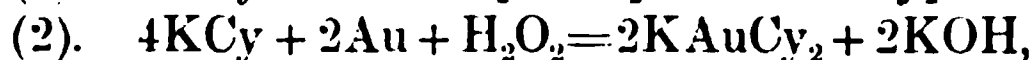
assume the ionic state, that is to say, its affinity for the positive electron is very much smaller than that of hydrogen; in fact, it is only by supplying a large quantity of external energy that it can be got to assume the ionic state. For example the solubility of gold in chlorine water is really accomplished at the expense of the energy due to the great tendency of  $\text{Cl}_2$  to ionise into  $\text{Cl}^\cdot$ .  $2\text{Au} + 3\text{Cl}_2 = 2\text{Au}^\cdot + 6\text{Cl}^\cdot$ . In view of this it is really extraordinary that gold should dissolve easily in the cold by the aid of  $\text{KCy}$  and  $\text{O}_2$ , which are both in themselves exceedingly indifferent substances. The older theories do not account for this, even with the aid of thermochemistry, and it is only the ionic theory which gives a satisfactory explanation. This explanation is that the product  $\text{KAuCy}_2$  is not a salt of gold, but the potassium salt of a complex acid; that there is therefore no necessity for much external energy, since there is no formation of gold ions. Again it is the general rule that “noble” (difficultly ionisable) metals are just the ones which easily form stable complex anions with cyanogen *e.g.*  $\text{Pt}$ ,  $\text{Ag}$ .

The function of the atmospheric oxygen has given rise to some discussion and it is not so easy to understand as it looks. The original equation of Elsner,  $4\text{KC}_y + 2\text{Au} + \text{O} + \text{H}_2\text{O} = 2\text{AuKC}_y + 2\text{KOH}$ , is misleading since there is no atomic oxygen in the solution and the energy required to separate the molecules of gaseous oxygen into atoms is liable to be lost sight of. The doubled equation,  $8\text{KC}_y + 4\text{Au} + \text{O}_2 + 2\text{H}_2\text{O} = 4\text{AuCy}_2 + 4\text{KOH}$ , has been verified experimentally so far as the ratio  $4\text{Au}:\text{O}_2$  is concerned. In the ionic form the equation reads,— $8\text{Cy}^\cdot + 4\text{Au} + \text{O}_2 = 4\text{AuCy}_2^\cdot + 2\text{O}^\cdot$  (secondary ion of water). Then since the dissociation of the second H atom of water is immeasurably small, this ion reacts with water to form  $\text{OH}^\cdot$ , viz.,  $\text{O}^\cdot + \text{H}_2\text{O} = (2\text{OH}^\cdot)$ . Combining the two we have,



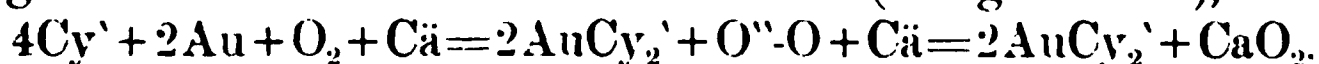
all non-ionised.

In opposition to this theory Bodländer in his "Chemie des Cyanidverfahrens," has suggested that hydrogen peroxide is formed as an essential factor in the reaction, and by performing the experiment in presence of lime, has actually obtained hydrated  $\text{CaO}_2$  in the reaction to the amount of nearly 70% of the theoretical amount. The equations which he puts forward are,—

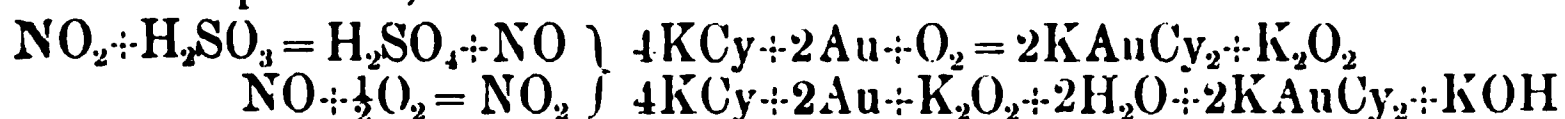


whence, by addition, we obtain Elsner's equation.

Now, although the second equation is perfectly substantiated by experiment, it seems to me that the first one is impossible. It may be split into several minor equations (1) conversion of  $\text{O}_2$  into atomic oxygen, (2) combination of oxygen and water to  $\text{H}_2\text{O}_2$ , (3) interaction of  $4\text{KCy} + 2\text{Au}$  to form  $2\text{KAuCy}_2 + 2\text{K}$ , (4) combination of  $2\text{K}$  with oxygen. Now the first three reactions do not occur of their own accord, *i.e.*, their heat of reaction is negative and it is hardly credible in absence of the actual thermal data, that the last reaction can compensate for all the absorption of energy due to the first three. As regards Bodländer's experiment in presence of lime, it is possible that the heat evolved in the formation of the solid  $\text{CaO}_2$  just suffices to make the whole heat of reaction positive, whereas it would otherwise be negative. This reaction would thus read (using the ions), —

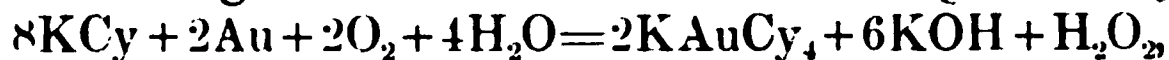


However, I am very uncertain about this. The comparison of the reaction with an ordinary catalytic action is quite misleading. If we take the case of the formation of  $\text{H}_2\text{SO}_4$  from  $\text{H}_2\text{SO}_3$  and  $\text{NO}_2$ , we have the two equations,—



*i.e.*, in the formation of sulphuric acid, a theoretically infinite amount of  $\text{H}_2\text{SO}_3$  is oxidised at the expense of the atmospheric oxygen by a fixed quantity of  $\text{NO}_2$ , whereas in the solution of gold once the  $\text{H}_2\text{O}_2$  has decomposed by the second reaction, the reduced compound (*viz.*, water), has no tendency to return to the state of peroxide. It is because  $\text{NO}$  will combine with oxygen even in presence of  $\text{SO}_2$ , that the sulphuric-acid process is possible, and it is just because the reaction  $\text{H}_2\text{O} + \frac{1}{2}\text{O}_2 = \text{H}_2\text{O}_2$  does not occur *per se*, that I think that Bodländer's theory is a perpetual motion.

Another erroneous idea that occurs in the literature is that it is possible for potassium Auricyanide ( $\text{KAuCy}_4$ ), to result from the ordinary leaching process. Even such a reliable authority as Ostwald gives the following reaction for the solution of gold in cyanide—



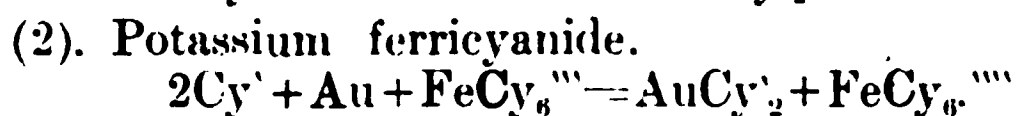
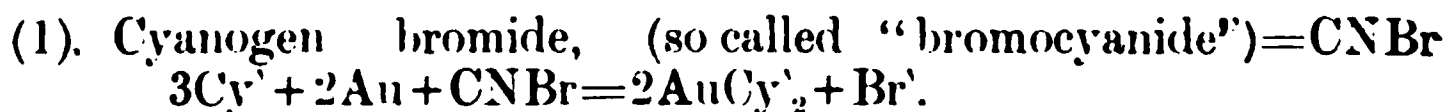
I am afraid that this reaction is wholly imaginary, for, not only is the ratio of Au to oxygen used incorrect, but also there is no experimental evidence to show that  $\text{KAuCy}_4$  can actually be formed from gold and cyanide. Perhaps the Association may be interested in seeing some of these substances in a tangible condition. I have prepared specimens of



AuCN,  $\text{KAuCy}_2$ ,  $\text{NaAuCy}_2$ ,  $\text{KAuCy}_4$ ,  $\text{KAu(SCy)}_2$ , and  $\text{KAu(SCy)}_4$  for the purpose of examining them under the polarising microscope and I find that this is a reliable method of identifying these substances in small quantity. Both K- and Na-aurocyanide give crystals which in polarised light give a magnificent violet colour with nearly straight extinction, whereas  $\text{KAuCy}_4$  gives none or only a pale yellow colour and forms thin hexagonal crystals. AuCN forms insoluble sulphur yellow hexagonal plates.  $\text{KAu(SCy)}_2$  is pale yellow, and  $\text{KAu(SCy)}_4$  is brownish-orange. Both of the latter are unstable and deposit their gold easily; even warming with alkali decomposes them.  $\text{KAuCy}_2$  forms rather sparingly soluble crystals frequently arranged in six-rayed stars with points resembling octahedra,  $\text{NaAuCy}_2$  is very soluble and forms very thin plates which are strikingly lustrous.  $\text{KAu(SCN)}_2$  is probably the form in which gold dissolves in ferric sulpho-cyanide, but I cannot succeed in isolating it from this solution because of its instability.

It has already been shown that the reason why gold dissolves in cyanide is that the oxygen removes the extra negative charges of the cyanide left over on forming aurocyanide—the equation being— $8\text{Cy}' + 4\text{Au} + \text{O}_2 = 4\text{AuCy}'_2 + 2\text{O}''$ . By studying this we can ascertain the factors which aid the reaction and those which slow it down. We can accelerate the reaction by increasing cyanide and oxygen together since by the mass action law the velocity of reaction is proportional to the quantity of oxygen multiplied by the eighth power of the cyanide concentration. Unfortunately the solubility of oxygen diminishes as the cyanide increases and we are forced to a compromise between them. I believe that wonderfully rapid extractions could be obtained if the leaching could be done in closed vessels under pressure so as to increase the oxygen concentration. Again the reaction will be slowed down by increasing the alkalinity (since that is one of the reaction products), and it is possible that too much lime may be sometimes used. However, it seems to be generally thought that lime is one of those good things of which we can't have too much. Again, if Bodländer is correct, and hydrogen peroxide is formed, it will slow the reaction if it accumulates.

**BROMOCYANIDE.**—Many inventors have been struck with ideas for doing away with the necessity for oxygen, and in fact any substance capable of taking two negative charges, will accelerate the process. This is well seen on examining Bettel's experiments done in absence of air. Those oxidising agents such as  $\text{KClO}_3$  which cannot take up more charges, have no effect. The following are ionic equations for some of the best known substances.



Nevertheless none of these reactions are quantitative since cyanide itself is easily destroyed by oxidation. In the case of cyanogen bromide it is of vital importance that free alkali should be absent, since alkali decomposes it almost at once. Judging from the analogy of the behaviour of  $\text{CNI}$  the reaction must be,  $-3\text{KOH} + 3\text{CNBr}, = 3\text{HCN} + 2\text{KBr} + \text{KBrO}_3$ , or in ions,  $-3\text{OH}' + 3\text{CNBr}, = 3\text{HCN} + 2\text{Br}' + \text{Br O}'$ , i.e. the substance is wasted since  $\text{KBrO}_3$  is not an oxidizing agent towards gold. If however, no excess of alkali is used it is probable that the reaction is,  $-\text{KOH} + \text{CNBr} = \text{KBr} + \text{HCN}$ , the latter then hydrolysing to  $\text{CO}_2 + \text{NH}_3$ , which will account for no cyanide being found after the action has occurred.

Mr. Alfred James has confirmed this destruction of bromocyanide experimentally, but without explaining it. He gives an experiment in which after distilling with  $\text{NaHCO}_3$  ("to drive off cyanogen"), and acidifying, he got the theoretical quantity of  $\text{KBr}$  corresponding to the equation  $\text{KCy} + \text{CNBr} = \text{KBr} + \text{C}_2\text{N}_2$ . I think however that the true reaction is,  $-3\text{KCy} + 3\text{CNBr} + 3\text{H}_2\text{O}, = 2\text{KBr} + \text{KBrO}_3 + 6\text{HCN}$ . On acidifying, the  $\text{HBr}$  and  $\text{HBrO}_3$  react to form bromine which is thus fully titrated with silver, using the same amount as if James' equation were true. Again the beneficial effect of  $\text{CNBr}$  is so much greater than that of cyanogen ( $\text{C}_2\text{N}_2$ ), that the effect must be ascribed to the tendency of the  $\text{Br}$  to ionise and so remove the extra negative charge left over on converting  $2\text{Cy}' + \text{Au}$  into  $\text{AuCy}'_2$ .

**PRECIPITATION.**—The recovery of the gold from cyanide solutions is effected mainly by the use of galvanic couples of which zinc forms the more electro-positive element (pure zinc is almost ineffective as a precipitant), and also by electrical precipitation. In both cases, as Mr. Caldecott has pointed out, the effect is really a reduction by "nascent hydrogen" and is therefore not an ionic reaction and is therefore not quantitative. In cyanide solutions, the galvanic couples, — zinc-lead and zinc-gold, decompose water continuously because the zinc takes on the charges of the hydrogen ions present and yet zinc ions cannot accumulate to stop the reaction, because they are continually converted into  $\text{ZnCy}_4''$  ions. The reactions are,  $-\text{Zn} + 2\text{H}', = \text{Zn}'' + 2\text{H}$ , (nascent hydrogen), and  $\text{Zn}'' + 4\text{Cy}', = \text{ZnCy}_4''$ . The nascent hydrogen then reduces the aurocyanide, but this reaction is an intra-ionic one and is therefore slow and incomplete,  $\text{AuCy}'_2 + \text{H} = \text{Au} + \text{Cy}' + \text{HCN}$ , or since alkali is always present, (viz.  $\text{OH}'$  groups),  $\text{AuCy}'_2 + \text{OH}' + \text{H} = \text{Au} + 2\text{Cy}' + \text{H}_2\text{O}$ .

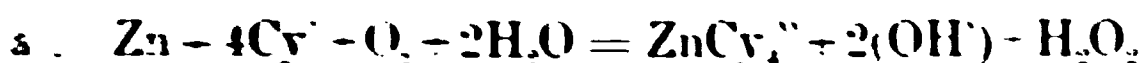
The action of the electric current is exactly the same; uncharged  $\text{H}$  atoms are liberated and reduce the aurocyanide in the fluid surrounding the kathode, but as the aurocyanide ions are comparatively infrequent, most of the  $\text{H}$  atoms have to combine with each other, forming gaseous hydrogen and wasting energy. Of course the same is true of the zinc process. The old equation,  $-\text{Zn} + 2\text{AuKCy}_2 = \text{K}_2\text{ZnCy}_4 + 2\text{Au}$ , is not only inconsistent with the facts, but is impossible according to the ionic theory, since  $\text{KAuCy}_2$  contains no gold kations, (as is shown by its not reacting with  $\text{SnCl}_2$ ).



There are two chief sources of cyanide loss during extraction, viz., (a), loss of volatile HCN which is mechanically removed with the hydrogen bubbles, (b), formation of methylamine by reduction of cyanide by nascent hydrogen. The former loss is due to hydrolysis of the cyanide into free alkali (ionised), and non-ionised HCN. Now ions are not volatile, therefore the alkali stays behind and the HCN is carried off by the bubbles of hydrogen. The loss is least with weak solutions, which are less hydrolysed.

(b). With regard to methylamine, this is formed by a non-ionic reaction between HCN and nascent hydrogen, the equation being  $\text{HCN} + 4\text{H} = \text{CH}_3\text{NH}_2$ . This is, I think the chief cause of the ammoniacal smell of the zinc-boxes, although doubtless a little ammonia is formed by the hydrolysis of HCN into ammonia and formic acid,  $\text{HCN} + 2\text{H}_2\text{O} = \text{NH}_3 + \text{CHO}_2$ .

OBSTACLES TO PRECIPITATION.—The great waste of zinc itself is due to the excessive E.M.F. of Zn-Pb and Zn-Au couples which decompose water of themselves, but this nevertheless is essential for the rapid formation of nascent hydrogen. The zinc becomes coated with its hydroxide and the action will eventually stop unless the coating is removed. The usual custom is to drip strong cyanide solution into the head of the box. This dissolves the  $\text{Zn}(\text{OH})_2$  with partial formation of soluble  $\text{K}_2\text{ZnCy}_4$ . The coating contains also almost invariably zinc ferrocyanide which is much more refractory and in this case it has been found advantageous to dissolve the coating with  $\text{H}_2\text{SO}_4$  and use the solution of  $\text{ZnSO}_4$  to precipitate (in a separate vessel) the excess of ferrocyanides in the solution. This is very crude: it would surely be preferable to prevent the formation of ferrocyanide at the beginning. A further explanation of the formation of this coating has been put forward by Bolländer, viz., that it is due to a direct action of hydrogen peroxide on the zinc. He shows that hydrogen peroxide is first formed at the expense of the dissolved oxygen of the solution and is then used up in oxidising more zinc, so that this goes on until all the dissolved oxygen has been destroyed. Cruse's determinations have shown that the solutions are in fact free from oxygen after passing the extractor-boxes. The reactions are—



This reaction is reasonable since zinc reacts with cyanide without the presence of oxygen. There are many causes of bad precipitation, but all may be said to act by the zinc getting coated with a layer which prevents contact between the "nascent hydrogen" and the auro-cyanogen ions. The chief factor is generally supposed to be too great alkalinity, but the only other factor of scientific interest is the deleterious action of copper in the solution, which is precipitated from dilute solutions before the gold and coats the zinc with an adherent film. This is due to copper coming next in order of E.M.F. to zinc in cyanide solutions. Tin and silver also precede gold.

I think I have now gone over all the salient points of the cyanide process from the newer point of view, and in concluding must apologise

for the inordinate length to which my interest in the subject has led me, for I cannot escape seeing that my contribution resembles the skeleton of a treatise on the subject, and, bulky as it is, has been compressed almost beyond the limits of intelligibility. I have in many places given utterance to un-orthodox views, and I hope that they will not be passed over in silence, and that the discussion may help to crystallise the somewhat diffuse ideas that are occasionally held in cyaniding circles.

#### 4. REDUCTION WORKS CHECKS AS PRACTISED ON THE RAND GOLD MINES.

By E. H. JOHNSON.

[Plate III.]

I am unaware whether the somewhat crude title is in itself sufficiently explanatory for the purpose of this paper or not, but it would, perhaps, be wiser to elucidate somewhat the meaning that is attached to checks on reduction work as applied to Rand Gold Mining. It is the effort to obtain accurate information, continuously, of the values before and after metallurgical treatment, and deduce therefrom the degree of efficiency obtained. It is, in effect, the accountancy side of the metallurgy of gold, and is computed from the results of careful sampling and assaying. It serves the purpose of determining the degree of skill and honesty with which the work is conducted, the amenability of the ore to the treatment to which it is subjected (a somewhat variable quantity even in this uniform proposition), and, most important of all from the metallurgical standpoint, to indicate the lines of least resistance where possible improvement may be effected.

The evolution of present systems of checking and recording reduction works values and extractions corresponds chronologically with the development of the various processes of gold recovery and the classification of the ore into the products which these processes necessitate.

From 1887 to 1890 the only process of extraction in operation on these fields was that of amalgamation, supplemented in some cases by blanket strakes, buddles, and in a few rare instances by Frue vanners. The products of these accessory devices were treated in Wheeler or Berdan grinding pans or by analogous systems of amalgamation, so that the total gold product was the result of amalgamation. Under these circumstances the value of the ore was regarded as the amount obtainable by amalgamation—which was commercially true at the time. Conversely, I have heard of the tonnage crushed being computed by the gold produced being divided by the reputed value of the ore. An excellent scheme of maintaining grade, but liable to very quick discovery and criticism if attempted under present systems. Little account was taken in most cases of the value of the residual sands—still less of the slimes—which were more commonly regarded as an expensive nuisance which it was desirable to get rid of. One method of getting rid of the tailings I saw attempted, was to run them into a neighbour's water dam. The result was painful to the attempter. In another case 1s. per Scotch cartload was paid for the disposal of 15 dwt. tailings, which were sold by the carter to the local builders. It was a matter of common congratulation among Barberton mill men in 1888 and 1889 that they were saved the necessity of conservation of tailings by

having a good-sized, periodically flooded river to run their tailings into. The successful introduction of the cyanide process by Mr. J. S. McArthur in 1890 materially changed these views. The tailings carried away by the Queen's river (Barberton), or the Blyde river (Pilgrim's Rest) would be a comfortable commercial asset if available to-day.

Before discussing the important influence which the cyanide process has exercised in elaborating methods of checking recovery, reference should be made to the Plattner chlorination process, which was early introduced on these fields (1890-1891), and is still practised, as a means of more efficiently dealing with the pyritic product of the Frue vanner and other higher class concentrating devices. The checking of this product is comparatively simple, the high value and comparatively small bulk warranting the expenditure of considerable labour to insure accuracy. Two works are in operation on the Rand at the present day: the Robinson Gold Mining Company's and the Transvaal Chemical Company's—the former mainly and the latter entirely a custom's works. The method here consists of frequent sampling, during weighing, for moisture determination, a large sample being retained for quartering down for the determination of value. The final sample is divided into three, one assayed by the seller, one by the purchaser, and the third reserved for reference to an independent assayer in case of disagreement.

The introduction of the cyanide process, with its economic re-treatment of the whole ore, has necessitated the sampling of enormous quantities of ore continuously. When it is remembered that a modern 200-stamp mill will crush 1,000 tons of rock per day, and this has to be sampled, not once, but at a number of different stages, each of which must be determined with the greatest possible accuracy, the operation becomes one of considerable magnitude. It has led to much ingenuity being displayed in the design of automatic samplers, and there are several varieties in use, each having its supporters, which give closely accurate results. The development to this stage of treating the whole of the crushed ore by cyaniding as well as by amalgamation has been one of evolution, only sands having been treated in the first instance, followed by the treatment of rough concentrates (produced by spitzlutte or buddles) in 1894. Various experiments on slimes treatment were made before the present decantation method was adopted in 1896, notably brick-making and burning with subsequent dry crushing to form a leachable product, and filter pressing in 1893 (since so successfully operated on the rich slimes of Westralia). Each development has brought with it the necessity of further checks, and efforts to further perfect methods are continuously being developed.

The first process of reduction commences with the hand-picking—or sorting—of the barren from the gold-bearing rock,

the pebble constituent of the latter forming the indicator by which the native sorter distinguishes the ore from the waste. The percentage sorted varies on different companies from nothing to 25 per cent. of the rock mined, the average being in the neighbourhood of 15 per cent. Here comes the first need for sampling to ensure that the rock eliminated is really valueless. It is one of the most difficult samples to obtain accurately on account of the large-sized pieces of rock discarded. I am afraid the only economical means of sampling this product with absolute accuracy is to induce the local county council equivalent to erect road-metalling stations at our waste dumps. So far they do not appear enthusiastic, although the condition of our roads proves the philanthropy of the suggestion.

Samples of the ore are occasionally taken during the transit of the ore to the mill and at the feed-chutes, but the usual practice is to determine values from a sample taken from the front of the screens—especially where inside amalgamation is not practised. The ore being then pulverized, a more accurate sample can be obtained from a smaller quantity than is possible from a much larger sample of the uncrushed ore. A clever device, designed by Mr. Adams, of the General Mining and Finance Corporation, to take this sample automatically has been tried, but the excessive vibration of the mill rendered inoperative what would otherwise have been a most useful instrument.

The pulp leaving the mill after amalgamation is sampled automatically. The automatic device consists in causing a slotted pipe to traverse the stream of pulp, either vertically or horizontally—the latter is more accurate—at intervals of time (or continuously, as in the Higham sampler), the portion passing through the slot forming the sample. Duplicate samples, before entering and on leaving the elevator wheel, are frequently taken to form a check sample. Another automatic sample is taken after concentration, and again after separation of the sands before entering the slimes plant. The spitzlutte product is usually hand sampled. The determination of values of each of these products again after treatment gives the residual value, and the difference the extraction. The graphic diagram given on Plate III. of the ramifications of sampling and gold determination necessitated by our present methods of reduction will give a more explicit idea of the work entailed. For more detailed description of surface sampling and its limitations, I would refer you to an able paper by one of our members, Mr. S. H. Pearce (see p. 750, vol. 2, *Proc. Chemical and Metallurgical Society of South Africa*).

The assaying of all these samples must be performed with the greatest possible degree of accuracy, as a small error multiplied by the large tonnage treated may mean a serious discrepancy of gold in a month's run. It is usual in modern

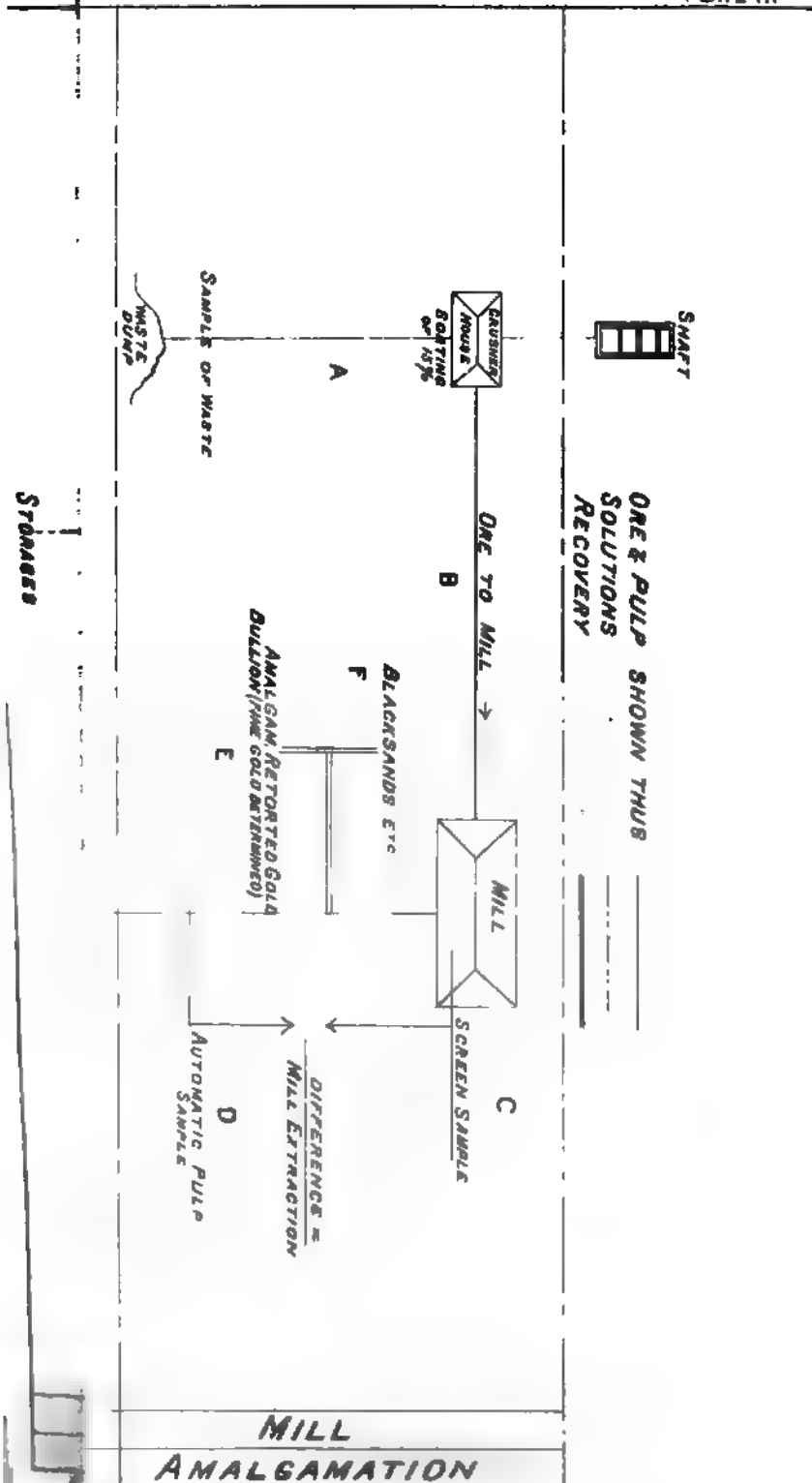
plants to determine reduction works' samples to 0.05 dwt. per ton, and solutions to 0.025 dwt. per ton. The determining of the gold to 0.05 dwt. per ton is equivalent to the determination of one part in eleven millions six hundred thousand, which needs careful work, and yet is equal to  $1\frac{1}{4}$  per cent. on a 4 dwt. material, or to £3,600 worth of gold on the tonnage crushed yearly by a modern 200-stamp mill. The important influence of so minute an additional recovery as one grain of gold (0.416 dwt.) per ton is not generally recognised by the shareholding public, and yet is well illustrated by a statement in the last Rand Mines' report, where it is shown that a slight appreciation in the realisable value of gold during the past year, amounting to 2d. per fine ounce, equivalent to two-fifths of a grain per ton crushed, had realised a sum of £5,240 on the year's operation of that Corporation. It may also serve to illustrate the industrial axiom that the increased capital and expenditure involved in skill and plant necessary to obtain the highest possible degree of efficiency, may be compensated many times by an improved recovery, although the amount of the recovery as indicated by assay may be within the margin of the experimental error in assaying.

The methods of assaying practised are practically those of the text-books except in a few minor details. The use of hydrated fluxes (*e.g.*, bicarbonate of soda, as recommended by most text books) is generally recognised as not conducive to the best work. The evaporation method of determining gold in solution has given way to a large extent to the more rapid and accurate precipitation method devised by Virgoe and improved by Whitby. Besides those assays which are directly needed for the checking of gold recovery there are many "works assays" needed for checking progress of work and the almost constant experimental working for improved extraction. It would be unfair, consequently, to close a paper of this description without expressing some appreciation of the splendid work that is being unostentatiously accomplished by our Rand assayers. The work is exacting, trying to the constitution from the usual high temperature of the assay office and to the eyes from the constant watching of furnace temperature. The constant repetition of similar operations renders the work to a degree monotonous, yet there is such an amount of enthusiasm for greater accuracy, more rapid work, and general advancement of metallurgical interests, that there is scarcely a class of workers to whom the Rand owes more than to its assayers. No department's work is affected to so large a degree by experimental work as the assayer's, and none accept it with such avidity. The conversion of the Rand from a mining venture to an industrial proposition, capable of mathematical treatment, is largely the work of the sampler and the assayer. It is not only the work itself which has advanced in accuracy and amount under pressure from improved

methods of extraction, but has carried with it to a large extent the education of the mining financial public to an appreciation of its great value. It may be within the recollection of some present, who were here in the early days of the Rand and Barberton, how an assay office was regarded by many as an unnecessary charge upon the capital and current expenditure.

There is one other matter which I should wish to allude to, which has some bearing on reduction works checks, and which is not generally very perfectly understood—even locally. That is, what is usually termed "plant absorption." This will always affect results over three or four months after starting a new plant, and subsequently also, in proportion, if more stamps are run. First, regarding amalgamation. Each plate will absorb up to 75 ounces gold. This is permanently retained by the plate under ordinary clean-up conditions, and can only be recovered by scaling. This, on a 200-stamp basis, means the permanent retention in the mill of 3,000 ozs.

Taking the same basis, a 200-stamp mill, running full, will crush 30,000 tons a month. At the end of that time 9,000 tons, or 30 per cent., will still be in the cyanide plant, either in collected form, or in various stages of incomplete treatment, the gold of which cannot be reckoned upon, or only partially. The daily amount of solution to be precipitated is approximately 2,000 tons, which will require 2,000 cubic feet of filiform zinc, or approximately 10 tons of zinc, which exposes an area to the solution of about 20 acres. The precipitated gold is distributed over this area according to the gold value of the solutions passed through. The process then becomes one of concentration, the zinc carrying the least amount of gold being brought forward to replenish the boxes of richer solutions as the zinc of the latter wastes away, and is itself replaced by new zinc. Estimating on the zinc returned to the boxes after a clean-up, amounting to 75 per cent. of the total box capacity, and carrying, say, 0.75 per cent. of gold, this means that upwards of 1,500 ounces are carried over to the following month, and, of course, each succeeding month. It would be extremely uneconomical to destroy all the zinc each month for the purpose of recovering this gold immediately. In addition, there are always gold-bearing by-products produced in the battery and cyanide works, which are usually only treated or disposed of every few months, and hence at the start their gold contents are not available. It will be plainly seen from this that the recoveries from a new and well-conducted plant do not represent the full economic value of the ore until these absorptions are satisfied. These are by no means gold losses but what, in accountants' parlance, would be termed "carried forward."







## EXPLANATION OF PLATE III.

- A. Sample of waste rock.
- B. Sample of ore to mill.
- C. Sample of ore taken from front of mill screens.
- D. Automatic sample of pulp after amalgamation. Difference between D and C equals gold extraction by amalgamation.
- E. Amalgam recovered. This is retorted (*i.e.*, distilled) mercury condensed for re-use. Residual spongy gold smelted into ingots. Ingots sampled and assayed for pure (fine) gold.
- F. "Black - Sands." Metallic impurities separated from amalgam during cleaning. Usually carries 6 to 15 oz. gold per ton. Sold to smelters on gold value.
- G. Spitzlutte (hydraulic classifiers). Separate heavier and coarser particles from pulp. Approximately 10 per cent. of total pulp and  $2\frac{1}{2}$  times the value per ton of sands (K).
- I. Residue sample of G after cyanide treatment. Difference of value between G and I represents gold extraction.
- J. Gold-Cyanide solution leached from G. Sampled on entering and leaving zinc-boxes. Difference in value shows efficiency of precipitation.
- K, L, M, N, O, and P undergo the same routine of sampling and determination of gold values as H, I, and J.
- Q. "Clean-up" of zinc-boxes. Resultant zinc-gold slimes treated by either methods (1) or (2) :—
  - (1) Treated with dilute sulphuric acid to remove zinc. Washed. Residue smelted in clay-lined crucibles.
  - (2) Smelted direct with litharge (Pb.O) and reducing agents. Resultant auriferous lead cupelled.
  - (1) and (2) Resultant bullion cast into ingots. Ingots sampled and assayed.-
- R. Slags from (1) sold to smelters.
  - „ „ (2) re-used if rich. Thrown away if poor.

## 5.—THE EVOLUTION IN THE TREATMENT OF BY-PRODUCTS ON THE WITWATERSRAND GOLD-FIELDS.

By M. TORRENTE.

(Plate IV.)

By the time every metallurgical operation has reached finality, a certain amount of material is left on the metallurgist's hands, which, either through its character, value, or cost of handling, will not stand further profitable treatment. These materials, however, very often contain considerable quantities of the original metal which is being exploited, and, as their bulk becomes almost mathematically increased in the course of time, they attain a very important value in the aggregate. This value is generally reckoned out per ton weight of material. Although the total amount accumulated may represent a small fortune, still, the expense which would be incurred either in the erection and working of the special plants necessary for their treatment, or in their transport to centres where such treatment is carried out, may be so great as to exceed the value of the product, or to render the margin of profit very problematical. In districts where the mines are very much scattered and far from all means of cheap communication, it is of common occurrence to find such accumulations, which, otherwise, would be a source of profit. In districts where the means of communication are cheap or within easy reach of a harbour, the same products find their way either to some customs work near at hand, or to some of the big metallurgical centres in Europe or elsewhere. These materials are known by the generic name of by-products, and it is needless to say that their nature varies according to the elements from which they proceed. By the time the amount of by-products accumulated in any mine reaches a respectable value, it constitutes an asset—very difficult of realisation sometimes, but nevertheless an asset. To extract the metals which are contained in them at a reasonable cost, so that a profit may yet be obtained from them, has repeatedly put metallurgists more on their mettle than all the rest of the metallurgical work of the mines. In spite of great ingenuity, failures are not uncommon, even after considerable sums of money have been spent in trying to solve the problem. Still, successes also do happen, and every one of them—no matter how small—marks one step further towards the ultimate object.

In a gold-mining district like Johannesburg, the metal contained in the by-products is naturally gold, with a small percentage of silver. Twelve or fourteen years ago, when only a few small batteries were in existence, and all transport had to be made by waggons for a good many miles and at an enormous cost, the working conditions of these gold-fields were such as to render the working of by-products out of the ques-

tion. At that time their production was not very considerable, and consisted principally of battery chips and slags from the smelting of the gold bars. The average battery manager even in those days knew that a fair amount of gold was carried in these chips, no matter how well he washed them; therefore he generally bagged them and piled them up near the mill to be treated *some day*. The slags produced in the smelting of the gold did not fare quite so well, and, after they had been pounded fine and cradled for whatever shots of gold could still be obtained, were very often thrown away, in some cases amongst the ashes from the bullion smelting furnaces, or returned to the battery to be further crushed and the liberated gold amalgamated. Other by-products at the time were the tailings produced by the batteries after the amalgamation of the pulp. Providence was very kind in this case, and the fact that this most valuable asset was still found on the premises when its treatment was rendered possible later on, was due to the flat nature of the ground, necessitating the then working companies to heap them up. If a good fall of ground had existed, or some friendly creek or river had been near by, these tailings would have disappeared, and an enormous amount of gold therefore lost. Later on, these tailings, which were formerly considered by-products, became products in themselves, giving up most of the gold they contained to the gentle persuasion of cyanide of potassium. Although the action of this chemical on gold, silver, and other metals was already well known, its successful industrial application to the treatment of tailings and other gold-bearing materials is undoubtedly the greatest metallurgical triumph of the last century relating to gold. It converted many gold-mining companies which were on the verge of bankruptcy into most flourishing dividend-paying concerns, gave quite a different aspect to many doubtful mining propositions, and gave employment to hundreds of men. The names of Messrs. Forrest and McArthur will remain household words so long as tailings are treated with cyanide, which, to all appearances, will be a long time yet.

Before very long the concentrates which had previously been roasted and chlorinated followed suit in the cyanide treatment, and, last but not least, the slimes—or very finest product produced by crushing the gold-bearing material in the battery.

The cyanide process greatly simplified the metallurgy of gold. The precious metal is precipitated from its solutions in various ways, and although the greater portion is very quickly and readily obtained as gold bullion, still the inevitable repeats itself, and further by-products of different descriptions are produced. If the gold has been precipitated on zinc we have a slag containing more or less metallic gold throughout the mass in shots, and which could be easily obtained by cradling; but some gold is so well assimilated by the slag itself as to

render its extractions impossible by any of the ordinary means at one time in use. I know of a company where the most careful measures had been taken to obtain the highest extraction from the slags. A special stamp battery was used for the purpose of crushing them through 700 mesh screen, and the pulp was amalgamated over special copper plates. A great amount of gold was recovered in this way, but the pulp, which was carefully collected in some settling vats placed below the copper plates and afterwards bagged, still contained from 10 to 12 ozs. of gold per ton. When this company ultimately sold the accumulation of seven years, they realised about £12,000—a no mean consideration.

If the gold from the cyanide solutions has been precipitated electrically on lead sheets, the lead bullion obtained carries the greatest part of the gold, which is readily obtained by cupellation, and is of a very high grade of fineness. The resulting bye-products are skimmings, metallics from the smelting operation and test bottoms from the cupellation. The metallics can be added to the lead when cupelling, but the others require special treatment.

It will be seen that every new process produces its own peculiar by-products, and they mostly follow the same direction. *i.e.*, the smelting works.

The enormous development of the gold industry, and the continuous increase in working capacity at the mines, also increased the by-product production very considerably. At the time the metallurgist could not give his attention to their treatment, and only knew of two kinds of by-products, *i.e.*, those which were very rich and could stand the expense of transport, etc., to Europe, and those which were of low grade, *i.e.*, from 10 to 20 ozs. per ton, and could not stand the price of transport at the time, and therefore were accumulated. So far he had only dealt with slags, etc., the product of smelting the battery gold. In many cases this only meant running the retorted gold into a bar ready for banking, and for the purpose of fluxing any small amounts of impurities contained in the retort gold, a small quantity of borax was generally added, therefore the proportion of slag in the gold produced was very small.

A Cyanide clean-up put a different complexion on the problem. To begin with, after the zinc boxes were cleaned out we were in possession of a product containing an enormous amount of zinc and other undesirable elements, such as silica, lime, alumina, etc., and the percentage of gold to the total of zinc gold slimes cleaned up was very small, seldom reaching 5 per cent. To this a proportionate amount of fluxes had to be added to eliminate the zinc and other impurities, and therefore the resulting slags were in enormous quantities compared to the gold obtained. I have known this proportion to be something like 2,000 ozs. of gold to about 6 tons of slag produced.

Cyanide works managers, metallurgists, and others had a rather lively time at this particular period; it was something new which had been sprung upon them. A process which enabled the amount of gold contained in thousands of tons of tailings, etc., to be caught into a few tons of zinc at a cost which, even at that time, was ridiculously low. The precious metals had yet to be extracted from this mass, and all the means at that time available were an ordinary plumbago crucible and a gold smelting furnace. Nobody, unless he has conducted personally a smelting operation of this description under the conditions stated, can possibly imagine the enormous amount of work it entails. To look after three or four 15 in. furnaces, and keep on charging gold slimes and fluxes from morning till night, and from night till morning, until the whole lot has passed through, is very hard work.

Once the contents of the crucibles were molten, they were poured into conical moulds, and, after cooling, turned over, and the resulting gold bullion detached from the slag.

This process was much too tedious, and it was not very long before big reverberatory furnaces were built, into which one or two dozen crucibles were placed at the same time, and their contents smelted at one heat. It was an improvement, but that is all that can be said for it, as the work connected with the operation was still very great, and made no difference to the quantity of slag produced or crucibles used. The next step was the treatment of the zinc clean-up with sulphuric acid. In good installations they were covered with a the purpose. In good installations they were covered with a hood dipping in a water butt, which hermetically closed the whole apparatus. A tube led from the top of the hood through the roof of the building into the air, and discharged the gases produced.

When the operation was completed, the remaining slimes were caught in a filter press, the cakes fluxed and smelted. This operation greatly diminished the amount of resulting slags, but still their content in gold was very considerable. The resulting gold bar could only be enhanced in fineness after a great amount of trouble, and every operation produced a subsequent by-product.

To obtain a bar of a high fineness, many things have been tried with more or less success. The most successful method is that of Mr. Crosse, who adds a small quantity of manganese peroxide to his fluxes. The resulting bar is undoubtedly of very high fineness, but it has the drawback that while it eliminates the base metals, it does the same with the silver, adding it to the slags resulting from the operation.

The latest improvement consists in placing the zinc clean-up in a reverberatory furnace, with additions of litharge and laboratory slag or any other convenient flux. The resulting

by-product, which is a slag, can be of very low value if the operation has been carefully carried out. The great drawback to this operation is the large quantity of gold which remains locked in the furnace, and also the heavy expenses of maintenance; it is nevertheless a great improvement on the other methods in use.

The litharge introduced with the charge, in being reduced to metallic lead, carries the gold to the bottom of the furnace. When the operation is completed, the lead bullion is tapped into moulds and cupelled—the resulting bar being merely composed of gold and silver—very seldom under 900 fine.

Still the work of improvement goes on, and hopes are entertained that slags will soon be produced which will carry only a nominal quantity of silver and gold; that a furnace will be built which will not lock up any gold, and that the maintenance will be greatly reduced as well as the time and labour necessary for the operation.

Such a result would mean the elimination of payable slags and by-products in the mines, and nothing would please the management more than to be able to get at the gold at once after the clean-up.

I was obliged, in a way, to refer to the Cyanide process, as it has so far been the most important factor in the production of by-products in the Rand—so much so, that the others could almost be ignored. The past two years have witnessed great advances in this process. In the near future all other by-products produced about a mine will come under the scope of the cyanide manager.

It may here be interesting to specify the principal by-products produced in a mine, *viz.*—

*In connection with the Battery.*—Concentrates, Black sands, Sweepings, Slags, Pots, Ashes, Battery chips, and Screenings.

*In connection with Chlorination Works.*—Pots and Ashes.

*In connection with Cyanide Works.*—Concentrates, Sands and Slimes, Slags, White Slimes, Prussian Blue, Scrapings, Sweepings, Skimmings, Dross, Litharge, Brick-dust, Test bottoms, Sump sediments, Ashes, Crucibles, and Liners.

As will be seen, the list is very considerable, and if, in an isolated mine, the best has to be made of it, the recovered gold must cost less than £4 per ounce. In a gold district of the immense magnitude of the Rand, these individual accumulations represent such an enormous value that it was not long before serious consideration was given to them. The by-products were at first disposed of to dealers, who bought them on the spot and exported them to Europe, or they were shipped direct by the companies. Later on the Rand Central Ore Reduction Company erected the necessary plant to deal with them. The usual way of dealing between the buyer (Rand Central) and the seller was as follows:—

The different by-products, properly marked and specified, were sent in by the companies to the reduction works. At the Rand Central they were received by the man in charge of the sampling floors. A day was appointed to do the weighing and sampling, for which purpose the parcels were taken singly, weighed, spread on the floor, well mixed, and sampled. This operation was performed in the presence of the representative of the company concerned. The moisture was immediately determined in a sample, and a further one selected for settlement. This last sample was taken in triplicate, one for the buyer, one for the seller, and one sealed by both parties for reference in case of need.

In settling the purchase the average value as ascertained by assay between the sellers and buyer was taken when the differences did not exceed 5 per cent. of the gold contents. If the difference exceeded this figure the reference sample was submitted to a bank, and the two nearest assays taken for settlement; upon this result payment was made.

After settlement the products were sent into the pan furnace shed, or into the blast furnace bins, according to their contents in gold. Slags in particular, and any products assaying over 30 ozs. of gold per ton, were treated in the pan furnace. In feeding the slags into the pan furnace a certain quantity of litharge was added, also a reducing agent such as coal or ground plumbago crucibles. The other by-products were added in such quantities as their nature would permit, so as to obtain a fluid slag. On reduction the litharge combined with the precious metals contained in the mass, and accumulated at the bottom of the furnace as lead. The slag was drawn as often as necessary, and when the lead at the bottom of the furnace was in sufficient quantity it was also tapped into moulds and could be immediately cupelled. The principal advantage of this operation consisted in the production of a lead gold bullion, generally of very high grade, and, as the cupellation followed at once, it did not take long to obtain the bar of gold. This point was most important, as the very high assay value of the products locked up quite considerable sums of money which it was important to release as soon as possible.

The disadvantages of the operation were, the great wear and tear of the furnace, the big amount of gold locked in it which could not be got at before it completely broke down, and the gold left in the resulting slag, which generally amounted to from 2 to 4 ozs. The quantity of lead was also considerable, amounting to from 8 to 10 per cent.

This department—first established at the Rand Central about eight years ago—gave at the start a good deal of trouble. The principal difficulty experienced was in getting the necessary men to work the department. Theories? Everybody was choke-full of them, but the actual work was a different



matter. When it came to handling the tools, and particularly to cupelling, somehow nobody could be found to do the work.

The Manager of the Rand Central, after convincing himself that such was the case, and having exhausted his patience, saw no other way out of the difficulty than that of importing a few practical men from Europe. They came in due course, and kept the process of making cupels a great secret, but the main thing was that the work was done, and done well. All the accumulations of slags and a few other rich products were soon disposed of, and the mining companies were pleased at finding a good means of converting these bye-products into cash without much trouble or delay.

Presently attention was given to all other products which, either through their nature or contents in gold, would have made their work in the pan furnaces too tedious or commercially problematical. To deal with these a blast furnace was erected, and here the above referred to products, often very silicious in their nature, were treated. The principal fluxes used were iron oxide and carbonate of lime. Litharge and galena produced the lead which acted as carrier for the precious metals. Sulphurets served to produce a matte with whatever copper might be present. The work of this furnace rendered possible the smelting of any product which might occur, but the high price of the coke used for fuel and of the necessary fluxes rendered its work very expensive. For every ton of by-products, from 3 to 4 tons of fluxes and fuel had to be smelted, and the margin of profit was therefore considerably decreased.

The slags produced by this furnace very seldom carried more than a few pennyweights of gold and silver, or more than 1 per cent. of lead. If of higher value they were repassed through the furnace. The lead produced, which carried the precious metals gold and silver and a small quantity of copper, was treated according to requirements. If the flux galena was abundant, the resulting lead was deprived of precious metals by the Parkes process. This consists in melting the bars obtained in cast iron pots of about 20 tons capacity. The copper dross is skimmed off, and zinc is next added to the mass of molten metal. Zinc has the extraordinary property of seizing on almost all the gold and silver present, and bringing it to the surface in something like the form of a crust, which is skimmed off. This skin—composed of zinc, lead, and precious metals—is sent to the pan furnace for the purpose of fluxing the zinc. When this has been done, the lead bullion produced is ready to be cupelled at once. The zinc may also be distilled and the remaining lead cupelled to obtain the gold and silver.

If galena is difficult to obtain, then the lead as it comes from the blast furnace is cupelled, and the litharge produced used again in the blast furnace as already described.

In cases where the use of galena results in a great excess

of lead bullion, this is refined and converted into marketable lead after the precious metals have been withdrawn.

In connection with the blast furnace work a fair amount of flux dust is produced. This necessitates the regular cleaning of the flues and dust chambers where it collects. The collected dust is simply added to the charges and returned to the blast furnace.

The matte is also passed through the furnace with the object of concentrating it, and, when its contents are considered sufficiently high, is shipped to Europe for further treatment.

All the refining which has been carried out at these works has merely consisted in the separation by cupellation of the gold and silver from the lead and other base metals as far as can be done in this operation. The bullion bars of gold and silver have been sent to Europe for disposal and further treatment.

A graphic table is appended, which will show at a glance the course of the by-products, fluxes, and secondary by-products, and will, I hope, render the foregoing pages relating to the Rand Central Ore of easy comprehension. (Plate IV.)

With the advent of the reverberatory furnace (pan furnace) in connection with the smelting of the Cyanide works clean-up, a great step in the right direction has been made. It enables the gold mining companies to do closer work than has been done heretofore, particularly if the gold zinc slimes have been acid treated previous to their smelting. The lead gold bullion which is obtained therefrom returns, after cupellation, bars of gold and silver bullion of a very high fineness, allows of the treatment of most of a mine's by-products, and produces slags, if the operation has been well conducted, very poor in the precious metals.

The results so far achieved are by no means small, and the work goes on nevertheless unabated, and a good deal has yet to be done in this particular direction before all the problems yet at hand have been solved. Will the Rand Metallurgist ever be satisfied? I hardly think so. He will keep on working, and although his progress may not be quite so rapid as it has been heretofore, every further improvement on actual practice will mean more gold for less money, which it seems to me has been the Rand's motto from the very start.

I have purposely left out of this paper any figures, as I never intended it to be statistical. In the proceedings of the Chemical and Metallurgical Society of South Africa will be found all data referring to almost every point I have dealt herewith. I have merely tried to review some of the work done in connection with the important problem of the treatment of the by-products produced in this mining area.

The exceptional conditions under which we are working here allows us to carry on our work under the most favourable conditions. Money is lavishly spent on the off-chance of im-

provement, skilled labour and materials of the highest quality are easily obtained. Besides the satisfaction of having attained a good deal of perfection already, the interest is kept in the work at the highest pitch by the knowledge of what is still to be done and the friendly competition existing amongst the generality of Rand Metallurgists in their endeavours to forward the interests of the Mining Industry in their own particular department. We must also not forget the great amount of assistance obtained from outside sources, assistance which has often proved of the greatest value to us.

Nothing pleases us better than the knowledge that we also do our best to help others working on the same lines.

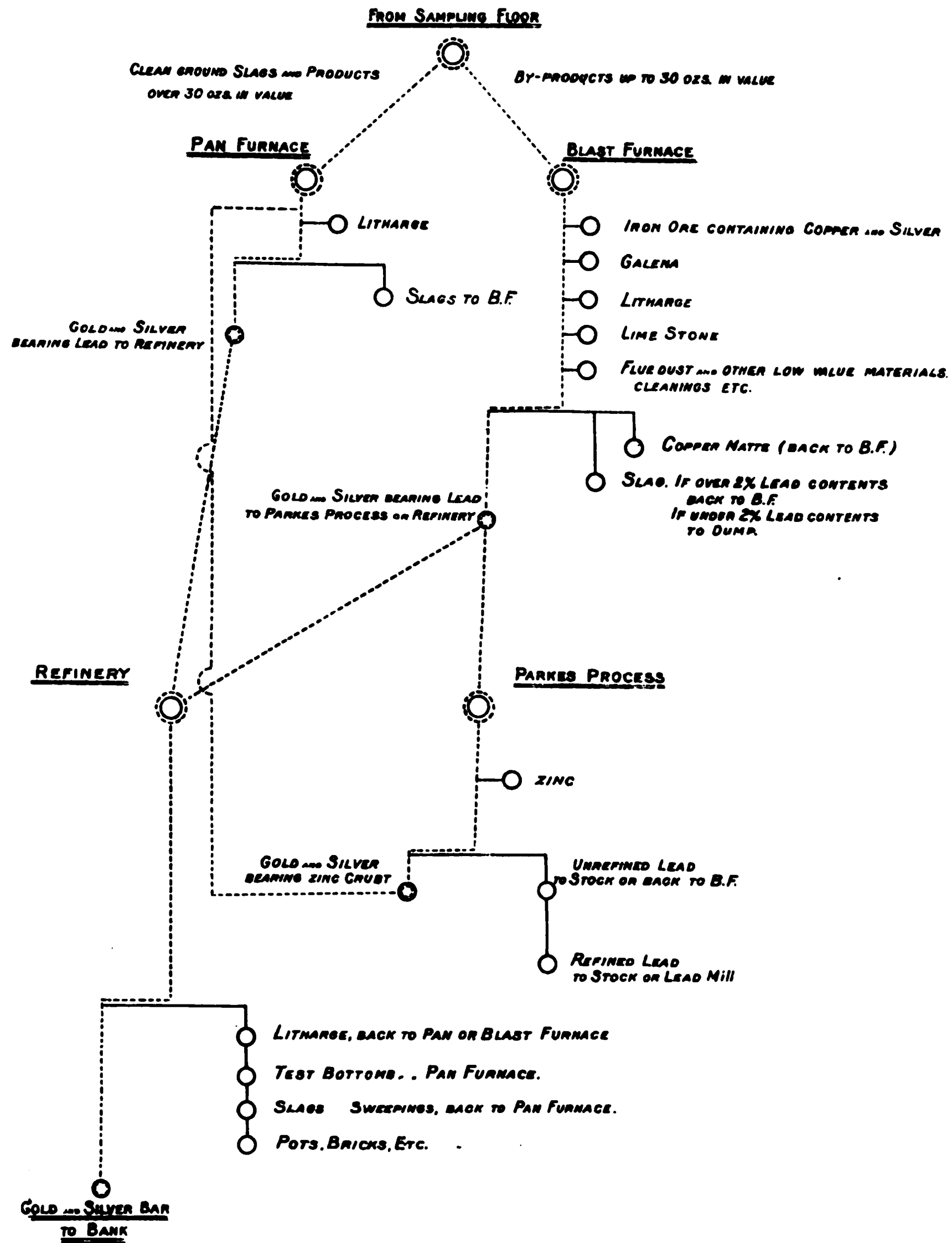
#### EXPLANATION OF PLATE IV.

The dotted line indicates the course followed by the precious metals contained in the by-products through the different departments or metallurgical operations.

—○ indicates the different fluxes or reagents added to the operations.

— indicates the different products outside gold and silver resulting from the different metallurgical operations.

○



*M. Torrente: The Evolution in the Treatment of By-Products.*



## 6.—THE GENESIS OF SOILS; WITH SPECIAL REFERENCE TO THE SOILS OF THE TRANSVAAL.

By ANDREW F. CROSSE.

When I was asked to read a paper before this section of the Association I did not wish to take up my own particular subject, to wit, metallurgy, as we deal with these questions in the Chemical, Metallurgical, and Mining Society.

I thought, therefore, that it would be of more general interest if I treated of a subject which has been unfortunately much neglected.

I little thought when I started upon this paper how absolutely the essential points had been neglected by the government authorities.

In the early days of the Reef "wild cat" schemes were sometimes started, and, I believe, batteries erected, where no reef existed. The people who started these "mines" may have made money, but they were not loved by their shareholders.

Now what have we done in this country? I suppose I can take up the position of a company shareholder, since I am a tax-payer, whilst we may regard the Government as the Directorate. Since we took over the country a certain section of the Government (or Directorate) has been most energetic in advertising the desirability of the Transvaal as an agricultural proposition, especially soliciting the immigration of English farmers.

The first thing a shareholder is entitled to ask for is the assays of the reef into which he has put his money.

In fact, on all our best-managed mines complete assay plans are available, giving full detail of the values of all developed rock.

When I undertook to read this paper I imagined that on application to the Agricultural Department I should be able to obtain and lay before you analyses of the typical soils of the country, and by these means, supplemented by comparison with analyses of typical European and American soils, be able to arrive at some conclusion as to the agricultural potentialities of the country.

Unfortunately however, up to the beginning of this year no such analyses have been made by the Agricultural Department. Criticism, you will agree with me, is superfluous.

I have therefore, been compelled to fall back on the synthetic method. Starting from the known rocks of the Transvaal and adjoining districts (for which knowledge we are indebted to the research of private members of the Geological Society of S.A.), I shall endeavour to deduce therefrom the nature of the soils formed by their disintegration.

### SOILS.

Soils in general may be divided into two main classes:—

A. Soils formed *in situ* from the sub-soil and rock on which they rest.

B. Soils which bear no direct relationship to the rock underlying them.

In practice no hard and fast line can be drawn between the two classes of soil, since aerial denudation and transport of the attrited dust plays, particularly in treeless countries, so important a part in ameliorating various soils, although each individual soil may have had a different origin.

CLASS A—SOILS *IN SITU*.

Such soils bear a definite relationship to the rock from which they are formed.

Speaking generally denudation and weathering have removed the more soluble portions of the rock and fully oxidised the ferro-magnesian constituents. Such soils are formed by the weathering of two classes of rock, igneous or plutonic, and sedimentary or stratified rock.

Rocks of the former class fall mainly under two heads, Acid and Basic. Soils derived from acid rocks (granite and syenite) are naturally poor in basic constituents. Potash is present only in small quantities, or may be almost entirely absent. Phosphates are not of common occurrence. Silicates make up the bulk of the soil, which hence tends to be of a sandy, friable nature; these soils may be coloured red from iron, but more often owe their colour almost entirely to organic matter.

In some cases where the parent rock contains much alumina the soils may be clayey. The great China clay deposits of Cornwall, Dresden, and Northern China are in truth soils formed *in situ* by the dissolving away of the soluble constituents of the granites upon which they rest.

Speaking generally, granite soils are poor and thin. In some cases they may be improved by the addition of phosphates.

Large tracts of moorland country in Germany have been brought under cultivation by a liberal use of "basic iron slag," carrying about 2.5 per cent. phosphoric acid.

In the northern hemisphere such acid soils are mostly covered only with whin and gorse: as, for example, the Dartmoor tors and the granitic Highlands of Scotland.

In this country large areas are covered by granite "bosses," and in all cases the soils derived from these rocks are poor and thin.

Large areas of such soil exist between Johannesburg and Pretoria, around Vredefort in the Orange River Colony, and up in the bush-veld, where enormous areas of granite occur. In the latter locality the soils are poor, except in the valleys and where basic rock intrudes through the granite. I regret that no analysis of these soils are available.

Granites containing mica give rise to soils of average fertility, the mica supplying the alkalies and alkaline earths needful to plant life.

Such granites are, however, not found in bulk in this country. In the low country fair-sized areas of mica granite occur, capable, under suitable conditions, of forming soils of average fertility.

#### SOILS DERIVED FROM BASIC ROCKS.

The chief basic rocks, which fortunately for the agriculture of the world are widely distributed, are diorites, gabbros, diabases, and basalts, including also those various volcanic rocks known as "Traps."

These rocks are, as the name implies, comparatively rich in ferro-magnesian, calcium, and potash-forming minerals.

They are readily weathered, and give free rich soils. The greatest corn country of India, that of the Deccan, is composed of basic rocks of volcanic origin, which form the huge plateau of the Deccan.

The soil of the Champagne, Moselle, and Burgundy Provinces of France are derived from basic volcanic rocks, as also the rich soils of Southern Italy, on which the finest vines are grown.

The lavas which from time to time poured down the flanks of Vesuvius and neighbouring cones are to-day the source of the richest soil of Italy. In Scotland the richest soil is that formed from trap rock, which covers the Lowlands, and the break is very noticeable where the traps give place to the granites of the Highlands.

Such soils contain, in addition to the silica, alumina and soda of soils derived from granites, much lime, magnesia, and iron oxide, and, if the rock contains much felspar, a due proportion of soda and potash salts.

Speaking broadly, it may be said that whilst granite soils are eminently unfertile, soils derived from basic (Hornblendic) rocks are eminently fertile.

Unfortunately the basic rocks in this country cover only a small area.

The Klipriversberg and other amygdaloidal diabases which occur in this country offer perhaps the greatest potential sources of good soil.

The fertility of soils derived from outcrops of these rocks is known to be above the average.

In the bush-veld the acid rocks are freely intruded through by pegmatite and nepheline-bearing rocks. Hence the soil of the river valleys is usually fairly rich.

The Marico country, where several intrusifs of nepheline syenite are known, is a good corn country.

So too, the soil in the valleys of the Pilandsberg, Enzilsberg and Zoutpansberg, in all of which basic rocks are found, in some plenty, is far richer than the soils of the high bush-veld, where granite ridges and kopjes break through the thin layers of sandy soil.



The valleys of the Magaliesberg, the garden of the Transvaal, are deep in red silt brought down from the hilly country, in some cases the rivers run, in the dry season, through deep cuttings in the rich red silt.

Rustenburg is perhaps one of the most fertile places, and possesses a rich red soil, probably derivative from the denudation of basic intrusifs.

In this connection I quote from a valuable paper read by Dr. Hatch before the Geological Society of S.A. on the Geology of the Marico District.

“North of the Zeerust Hills the true bush-veld begins, the surface of the country being covered more or less thickly with scrub and bush, consisting chiefly of various species of thorn trees, together with *Beukenhout*, *Olivenhout*, *Syringa*, *Tambooti*, and *Hartekol*. In general the Marico District may be taken as an example of the close relation existing between geology, physiography, and agriculture; the well-watered, thickly-wooded, fertile and populous Marico District being practically co-terminous with the synclinal area with its diversified slate, quartzite, limestone, and basic igneous formations. Outside the limits of the syncline, and across the borders of the Protectorate, we find a rolling granite country, comparatively speaking treeless and waterless; a grazing, not an agricultural country, and inhabited almost exclusively by native races.”

Dolerites occur in intercalated sheets in the Karroo Series, and attain a maximum thickness of 300 feet.

The Eastern Transvaal is largely overlain by the Karroo beds, but the outcrops of the dolerites are uncommon, and do not present any very large area.

In another age, when denudation lays bare these vast dolerite sheets, now covered by hundreds of feet of newer series, the soil of the present O.R.C. should be of exceptional fertility, seeing that the O.R.C. is covered by the Karroo beds. Unfortunately that period is too far distant to be of more than the most remote theoretical interest.

#### SOILS DERIVED FROM AQUEOUS (STRATIFIED) ROCKS.

Here again the general character of the soil is that of the rock from where it is derived, but no such simple classification is possible as is the case of the igneous or plutonic rocks. One may, however, divide these rocks into two classes—“Detrital,” *e.g.*, sandstones and clays, and “Calcareous,” such as chalks and dolomites; the former class may be considered as derivative soils (using the word in a wide sense) deposited under water.

By subaerial disintegration they are resolved back into their several constituents, plus such mineral matter as may have percolated into them during the period of quiescence they passed in the form of rock.

In this manner the phosphates of the “Cambridge green sand” represent the detritus of former glauconitic marls and

chalks, eroded by and laid down by the sea in Cretaceous days, and after ages of quiescence thrown up to the earth's surface, where by their weathering, they provide phosphates for the plants of another age.

Sandstones are usually unproductive of good soil, consisting as they do, mainly of silica, the soluble salt of the rocks, from whence they were originally derived, having been long wasted away.

The basement rock of South Africa is granite, which extends from the Cape to the Zambesi, here and there asserting its presence by means of huge bosses, examples of which we have already noticed.

It is, then, only natural that, having regard to the original rock, from which in all probability, the aqueous rocks were derived, we should find that those areas covered with grits, sandstones, and other aqueous rocks are of no potential value to agriculture.

The Waterberg sandstone, which covers an immense area in the Northern Transvaal, is about as unproductive as the English millstone grit, and the sandstone portions of the Karroo Beds are almost equally valueless.

Clays give rise to a large variety of soils, particularly on outcrops against chalk or sandstone.

Clays, however, do not occur in bulk in the Transvaal, and we may therefore, neglect them.

Shales, as may be seen from a casual inspection of a geological map of the Transvaal, occupy large areas; in chemical composition they are little different to the sandstones, indeed many of them are virtually quartzites.

These shales are very free from organic matter. Speaking generally, one is compelled to say that the aqueous or sedimentary rocks of the Transvaal are of little or no potential value as soil producers.

#### CALCAREOUS AND DOLOMITIC ROCKS.

True chalks do not occur in the Transvaal. This is unfortunate. The Transvaal is most unfortunate in its selection of rocks, viewed from the agriculturist's point of view, for chalks always contain a certain proportion of silica and phosphate, and by this slow weathering (chiefly due to the solvent action of carbonic acid), leave behind a thin layer of rich phosphatic soil.

The dolomites are easily disintegrated, but their porous nature allows the soluble constituents to be washed out by subterranean drainage.

Contact soils formed where granites outcrop through dolomite should, if they can be kept moist, prove fertile. Dolomite soils are always dry on the surface, drainage being very efficient in such formations.

Such soils occur over large ranges of country in the Western Transvaal.

They are not distinguished by any particular fertility, or the reverse. The Western Transvaal possesses a painful uniformity in this respect.

One rides over miles and miles of rolling grass land, the staple product being Kaffir corn and mealies, and these only in patches. Where aqueous rocks break through the dolomite, or dolomite, fairly rich soils are formed, if they can be watered.

The valley of the Schone Spruit by Sterkstroom is exceptionally fertile; it is on the line of outcrop of the dolomite, and well watered.

At Lichtenberg, in the Western Transvaal, the dolomite soils form, when irrigated, exceptionally good potato-growing soils.

The soils are however, very shallow, and can in few cases be adapted to the deep culture required for potatoes.

Good cereal crops appear to be raised in the parts of Lichtenberg accessible to the water furrows. Many of the farmers, however, are handicapped by the want of a proper rotation for these crops; the leguminiferae might be included in a two-year rotation with advantage, as they supply a large amount of nitrogenous matter to the soil. It is customary to grow two crops per year on the irrigated lands in these richer districts.

The constant growing of cereal crops has had an injurious effect on the land; irrigated land is too valuable to lie fallow, and I doubt if, in this dry climate, fallowing would be of any real gain, as nitrification requires not only warmth but moisture. Nothing is more fatal to the germs of nitrification than prolonged exposure to the sun in dry soils.

It is a point amongst many, which might well be investigated by the Agricultural Department.

#### DERIVATIVE SOILS.

So much for soils *in situ*; we now pass on to the consideration of derivative soils.

These soils, as the name implies, are derived from rock or soils occurring in some other district, and have no relation to the rock directly underlying them. No hard and fast line can be drawn between the two classes of soil, since all soils *in situ* owe something to wind-borne dust, and all purely derivative soils owe certain constituents to underlying rock.

The chief agents of denudation and transport are changes of temperature, wind, and rain; we may briefly consider their action, and the general type of soil produced by their agency.

Soils *in situ*, as we have seen, are formed by the weathering of the rock under such condition as may prevent the removal of the disintegrated portions. It follows then, that the composition of derivative soils is dependent on the nature of the rock from whence they are derived, but they differ in this important respect from soils *in situ*, viz.: Soils *in situ* have only one type

of rock to serve as a base, whilst derivative soils may be derived from several types of rock.

#### WIND-BORNE SOILS.

These soils, which cover numerous areas in Eastern Europe, China, and America (where they are known as Loess and Adobe respectively), are unfortunately unknown in South Africa.

They require for their formation long periods of prevailing winds blowing across highly desiccated country, free of vegetation.

The Loess of China is in places 2,000 feet deep, and has completely altered the original contour of the country; valleys have been obliterated, the streams having cut deep gorges through the yellow loam, producing secondary drainage. It also occurs in even greater thickness in America. Strictly aeolian soils do not occur in this country. The Kalahari country, the nearest approach to the steppe conditions formed in South Africa, is too thickly grass-grown to give rise to dust storms of any magnitude.

Local dust storms, of course, occur all over the country, particularly in Johannesburg, but their effect is too slight to play any important part in ameliorating the condition of the soils.

Aeolian deposits are entirely absent in the Transvaal.

#### WATER-BORNE SOILS.

As you all know, rivers rising in high ground lose their initial velocity when they descend to the plains, and hence deposit the major portion of the silt they bring down from the hilly country.

The "flood valley" of a river is the usually most fertile portion of its course, and as the river works downwards it leaves terrace on terrace of rich alluvium. The value of alluvium as soil is obvious.

Derived from various rocks, enriched by organic matter, hydraulically separated from all heavy rock particles, it is spread in layers on the flood valley.

It is as though the rivers were huge carriers tearing away after every flood in the hilly country, all the decomposed and weathered rock, sifting out the coarse particles, mixing up organic matter, and finally spreading it out in the low country. The composition of alluvium is an epitome of all the rock and soil traversed by the river which has deposited it.

Unfortunately alluvial soils of large extent are unknown in this country. We have nothing to compare with the huge alluvial deposits of Egypt, of the Ganges, or Mississippi-Missouri Deltas.

True, along the Vaal are found alluvial soils, but this alluvium is not of good quality, being derived from granite and acid rocks. In the hilly country of the N.W. Transvaal, as I have already pointed out, local deposits of rich alluvium are found,

and are responsible for the fertility of the river valleys.

In the low country alluvium occurs in some plenty, but the climatic conditions are against successful agriculture, at any rate as far as the agriculturist is concerned.

#### GENERAL REMARKS.

It will thus be seen that, speaking generally, there is little *prima facie* evidence in favour of the existence of large tracts of fertile soil in this country.

It remains now to consider the influence of climatic conditions on the soil.

The climate of the Central Plateau is, as you are aware, extremely uniform.

For nine months of the year the land is dry and sun-cracked. Heat there is, in plenty, during the day, but moisture none.

Hence, during these months there is little scope for those most useful of organisms, the bacteria, which induce nitrification.

The conditions for rapid nitrification are warmth and moisture. Hence, during nine months of the year nitrification is virtually a negative quantity, and the soil loses the effect of the greatest agent of nature for the fertilisation of soils.

For the other three months it rains, generally in heavy down-pours, which wash the surface of the land and carry off such nitrates as may have been formed at the surface of the soil. I do not think that the Agricultural Department could find a more useful subject for that investigation than the influence of the sun on nitrification in particular and on the soil in general.

I think that they will find that our "pale, dry, healing blue" is not altogether an unmixed blessing; having arrived at some definite conclusion, it will be for them to propose a remedy, either natural or artificial.

The popular idea is that all we require is irrigation; now I maintain (and until the Agricultural Department disproves my deduction by actual results obtained I consider that I am justified in maintaining) that large tracts of land in this country, which offer no insuperable engineering difficulties in the way of irrigation, although involving large sums of money, could never repay the initial expenditure.

To obtain successful returns from irrigated lands, either the soil must be rich enough to stand increased demands upon it, or such constituents as it may lack must be added to it.

These deficiencies may be met either chemically or naturally; for instance, most of you are aware that the leguminiferae are capable of abstracting nitrogen from the air and so enriching the soil, but no natural process is capable of supplying phosphates or alkalies.

At the commencement of this paper I made a few general

remarks concerning "wild cats" and similar propositions. I do not wish to say that agriculture in this country is a "wild cat"; far from it, for we do know of the existence of many rich pockets; but I do say that (to maintain our analogy) that is an extremely "low grade" proposition, and results obtained from a few "pockets" must not blind us to that fact, and it is well that the Directorate (in our case the Government) should fully realise the fact.

I think it a very important thing that the real value of this country should be thoroughly realised both by the Home Government and by the more intelligent of the British taxpayers. By "value" I mean both the mineral and agricultural value of the country.

There has been a decided tendency on the part of several well-known writers to over-estimate the mineral resources of the country. The value of the gold in the Transvaal has been worked out to figures of gigantic dimensions, and I am quite certain that we, at present living in the country, are suffering from this cause. The taxes which we have to pay could be easily borne if we were only in that theoretical position to which the possession of such enormous potential wealth entitled us.

Unfortunately betwixt theoretical and practical yield there is a great gulf fixed.

We measure our veld by the million acre, and your uninformed Home expert on South African affairs divides the land into fifty-acre plots and dreams of a contented farmer and his family subsisting on each plot.

Need I dwell on the folly of such schemes?

The voortrekker, with his farm of four to six thousand acres, and sufficient Kaffir labour, undoubtedly made farming pay, but owing to the well-known reproductive power of the Boers, and the absence of any law of primo-geniture, the size of these farms is decreasing in a geometric ratio, and to-day, in the less fertile districts, the sons of prosperous voortrekkers are reduced almost to the condition of the Irish peasantry, and gain but bare subsistence from the unkindly soil.

It is, then, the bounden duty of Government to thoroughly study the position of things and estimate facts at this true value.

God forbid that well-meaning enthusiasts with no local knowledge should introduce the English yeoman farmer type, only to reduce them to the level of the Bijwooner class. The lower-class Boer is a product of his environment. The indiscriminate settling of small farmers in this country would only lead to an increase in a class already too numerous and of no value to the State.

It is the duty of those to whom is committed the building of nations to see that the foundations of the State are free from all weakness. Weakness in the superstructure may be remedied; weakness in the foundations demands, sooner or later,

complete reconstruction. Generally speaking, agriculture is not, in this country, a paying concern, yet I think that scientific farming on a fairly large scale would raise the status of the agriculturalists and eventually could maintain a large class comparable to the yeoman class, to whom England and her Colonies owe and have owed so much.

If we, of the Transvaal, are ever to become a nation, the existence, the assertive existence, of such a class is of absolute necessity.

Mineral wealth alone can never make a nation.

This country has been richly endowed with gold, diamonds, and other minerals, but one must not forget that every ton of mineral matter removed leaves so much less behind. For this and other economic reasons I consider it to be the duty of the Government to intelligently foster agriculture, by applying some of the money obtained by the taxation of the mineral industry to the furtherance of this object. So that, in that day when the last "deep-deep level" has been worked out a lasting monument to the industry may be left in the form of a great agricultural industry.

I should like to see a map of the Transvaal, showing the agricultural value of the soil in various localities, also giving average rainfall and other data. The establishment of small experimental farms in different localities, not only in localities of known fertility as is the present system, would also help to determine the most deductive methods for the different conditions obtaining.

Science enables us to cultivate land barren to previous generations; let us therefore call to our aid all that science can give, supplemented by intelligent adaption to local circumstances. The population of the temperate zones increases rapidly, particularly the population of our Empire. Each day sees our Empire more dependent on external food sources. Here in the Transvaal we have huge possibilities for scientific farming on a large scale. The yield per acre will be small, but South Africa is large. Our own population is increasing. We all hope to see it increase yet more rapidly, if this Colony is to form a real unit of the Empire. It is necessary, therefore, to make adequate provision for the future, remembering—

"After us cometh a multitude:

Prosper the work of our hands,

That we may feed with our land's food

The folk of all our lands."

It may be that some will consider that I have adopted an altogether too pessimistic tone. Believe me, whatever motive may have influenced my remarks, that of pure pessimism did not. When I reflect upon the sacrifices which this country has demanded, the heroism, the hardships of the Voortrekkers, pioneers second to none of all those whom fate has sent and still sends to explore the unknown lands, to mark the first trail that



in time becomes the highway of a nation ; of the cost, not to be measured in millions, of the late war, I feel that in the Eternal Fitness of things some great end must attain from this sacrifice.

It is because I believe that we can build a nation here, because I believe that the agriculturist will be, must be, the backbone of that nation, that I have endeavoured to point out some of the difficulties which beset those who would try to force this class into being before the times are ripe.

For fifty years this country has waged intermittent warfare against external and internal forces, but now we have entered upon a longer, sterner war, the fight with Nature. We have entered upon that long contest wherein successes are few, wherein the end is but slowly attained, but whereby, I believe, we shall attain the victory.

My thanks are due to my assistant, Mr. Gerard W. Williams, for the material assistance which he has given me in the compilation of this paper, more especially in the geological portion.



## 7.—THE CHEMICAL INDUSTRY OF THE TRANSVAAL: A FORECAST.

By W. CULLEN.

The Gold Mining Industry of the Transvaal is such a large factor in the country's prosperity, that we occasionally forget the possibilities of others. Chemical industry is at present represented by the Dynamite Factory and the Chemical Works near Boksburg, and neither of these works would have been in existence to-day had it not been for a measure of protection granted them by the old regime.

Outside these two concerns there is practically no other chemical industry. True, a small soap factory carries on a precarious existence, and a glass factory has recently been started in the neighbourhood of Johannesburg. The Hatherly glass factory is now closed down, and the same remark applies to the famous distillery. The cement works at Daspoort, which are equipped with modern plant, now make an excellent cement, which compares favourably with the best European brands. The factory is built on an excellent clay deposit, and the lime is found in the immediate neighbourhood.

Beer-brewing is an important industry, and is daily becoming more so, but it is not generally referred to as a chemical industry.

This, then, exhausts the not very formidable list of Transvaal chemical industries.

It is certain that the term "metallurgy" as applied to these fields will soon have a much wider significance. At least one excellent deposit of zinc is known, and surely it is possible for us to make our own zinc discs in the country—more especially as the price of spelter has for a very long time averaged £21 a ton in Europe. Lead simply abounds in the form of galena, and generally assays very high in silver. The metallurgy of lead is very simple, and the greater attention now being paid to sanitary matters will create a demand for pipes and sheets—this, of course, apart from the present demand, which is not inconsiderable.

Then, again, we have enormous deposits of copper, the extraction of which by both the wet and the dry process should offer no particular difficulty when the question of transport has been solved. In this country there is already an enormous demand in the form of plates, leads, etc., etc.

Going still further, we have tin in abundance, and, it is whispered, Radium also. The latest metal to be added to the list is Platinum; but, when all is said and done, the most important metallurgical industry will be that of iron. The deposit of haematite north of Belfast is said to be one of the most marvellous in the world, not only on account of its extent and the purity of the ore, but also from the fact that the necessary lime and coal are also right on the spot. Those responsible for the idea are very hopeful, and the figures with

which I have been furnished are quite encouraging—provided that the railway can do its share. When the day of blast furnaces and convertors arrives we shall have basic slags for the farmers as well as ammonia and cyanogen for the mines.

The heavy freight and railage charges form a natural protection to any local industry, and naturally this applies with greater force to chemicals which have to be carefully packed, and therefore have a high gross weight, than to metals such as spelter, which require no particular looking after.

The importation of chemicals for 1903 amounted to £500,000, and this is a very large figure. Cyanide was, of course, the principal item, and will remain so, but the attention sanitary matters are receiving has created a large demand for bleaching powder. Sulphuric acid—already a large item—will increase, and even if concentrates are treated by a modified process there is still plenty of pyrites in the country. The dynamite industry will no doubt double itself in a few years, and the same remark ought to apply to all local industries of whatsoever kind. Prior to the war artificial manures were practically unknown, but the importations from Europe have already assumed very large dimensions. There is no reason why all this should not be made locally. True, some of the principal ingredients—for instance, apatite—would require to be imported, but a deposit is certain to be found in this country some day.

The importations of alkali are now assuming large dimensions, but when they are a little larger they will be manufactured in the country. Seeing that it hardly pays to return empty cylinders to Europe, it ought to be possible to get them filled with oxygen and carbonic acid here in Johannesburg. Acetylene is becoming daily more popular as an illuminant in the outlying districts, and the manufacture of calcic carbide is also certain to be taken up soon.

It is not possible to hold out any immediate prospect for a large soap industry, but it is not improbable that candles will be made in the near future from shale. Then, as mealies and potatoes become cheaper, there is no reason why Hatherly should not start again and become more of a genuine industry than it was before. Plenty of good whiskey is made from potatoes and maize—prejudices against them notwithstanding.

The manufacture of cyanide has assumed great importance within recent years, but very little has been published on the subject. From all that can be gathered, the old process of first of all making Ferrocyanide seems to hold its own, but immense quantities are obtained during the purification of illuminating gas—as also from blast furnaces. A source of potash has just been found which should make the Ferrocyanide process possible here, and surely there is enough nitrogenous organic matter and old iron to spare in the country. I shall be very much surprised indeed if we do not hear of the manufacture of

cyanide in this country very soon. The cyanogen recoverable from the gas works' by-products is hardly worth speaking about now, but this will soon be otherwise. Apart from the sulphocyanide—the principal gas works' source—a very successful process is that of Sieperman, which has as its principle the passing of ammonia over heated charcoal impregnated with potash. This seems simple enough, but, naturally, if our gas works' ammonia were utilised thus, there would be none for making ammonium sulphate. We need not trouble about making chemically pure cyanide out here; what is wanted is available cyanogen, and if parcels are bought on assay no harm is done to the buyer or the seller. No doubt when better times come the government might see its way to afford an industry such as this a small measure of artificial protection until such time as it found its bearings.

Reference has already been made to artificial manures and to the utilisation of the gas works' liquor for sulphate of ammonia. However, all the gas works of South Africa combined will soon be unable to meet the demand for artificial manures containing this ingredient. The other principal materials, such as nitrate and phosphate, can be landed as cheaply at any South African port as at Liverpool, and, considering that they are carried at a very cheap rate while the finished manure is heavily taxed in this respect, it should be possible to build up a flourishing local industry.

Hitherto sanitary matters have not received very much attention, but the community is beginning to realise that a liberal use of chloride of lime is an excellent insurance against troubles of all kinds. Already the demand is large, and when the Chinese come it will be larger. To give an idea of the natural protection which would be afforded to an industry such as this, it may be stated that the f.o.b. price per ton in London is about £4 10s., while the lowest price at which it has ever been sold here is £18—railage, freight, and insurance charges accounting for the difference. This industry is bound to start very soon, seeing that all the ingredients are found in the country.

These prospective industries taken singly do not make a very gallant show, but, combined with those industries already in existence, such as explosives manufacture, the grand total is not to be despised. It is not pretended that any one of these will come into operation at once, but it is the opinion of the writer and others competent to judge that the time is not far distant when we shall have a large and a genuine Transvaal Chemical Industry.

## 8.—THE CONTACT PROCESS OF SULPHURIC ACID MANUFACTURE.

By E. WEISKOPF.

I am well aware that the subject which I introduce to your notice to-day is not one which is of great interest to the general public, and this mainly for the reason that we cannot yet boast of a general chemical industry in this country. But you will all admit that this Colony offers excellent conditions for the development of such an industry, and I am perfectly convinced that if only once a start is made it will grow and prosper, and help to make us more independent in every sense of the word.

Now the manufacture of sulphuric acid is the basis of almost every chemical industry, and if we ever contemplate establishing any such industry in South Africa, we shall certainly have to face first of all the manufacture of sulphuric acid.

Very little has been heard of the new contact process in connection with actual manufacture, and it is only quite recently that some information has been made public. Nevertheless it has already led to an entire revolution in the manufacture of sulphuric acid at home, and it also opens prospects for the establishment of a *local chemical industry*, which a few years ago would have been considered an impossibility.

It may be said at once that the local Dynamite Company, who themselves consume about 15,000 tons of sulphuric acid yearly, have anticipated this for some considerable time, and are installing an additional plant for the manufacture by the contact process, which will enable them to meet any demand, no matter how great.

It is not the purpose of this paper to point out the great importance of sulphuric acid for the chemical industry, nor is it the intention to discuss the possibility of such an industry in this country, but one cannot help calling attention to the vast amount of *concentrates* which certain mines produce, and which with little trouble could be used for the sulphuric acid manufacture.

I have in mind certain mines which concentrate their ore in frue-vanners, and which, after extracting their concentrates, obtain a residue in many instances, known to me personally, running as high as 45 per cent. of iron pyrites and about 4 dwts. of gold.

In considering the possibility of using these concentrates for the manufacture of sulphuric acid, we do not only lay the foundation stone for a new local industry, but we also involve to some extent the mining industry itself.

You all know that the last traces of gold in the concentrates, referred to above, can only be recovered with difficulty, chiefly on account of the pyrites, and with such poor material it would not pay to remove them by roasting.

There are, further, concentrates which are rich enough to

stand the cost of transport to England, but which cannot be treated properly here.

You also know that frue-vanners have lately gone out of fashion, and I believe that I am correct in saying that this is chiefly due to the fact that, with finer screening and more prolonged extraction with cyanide, good results can be obtained at a lower cost than by roasting with a subsequent extraction. Would this position of affairs continue if there were an opportunity of disposing of the concentrates at a fair price? I am not sufficiently *au fait* with our mining industry to be able to express a definite opinion one way or the other, so I shall therefore leave it an open question for the present.

There are undoubtedly some technical difficulties to be overcome before any such scheme could be realised, but I firmly believe that they are not insurmountable.

And now, after having endeavoured to show that a paper on the contact process is more or less of general interest, I shall try and give you as briefly as possible the history, theory, and a brief description of this new method of sulphuric acid manufacture.

What are generally known as *contact processes* are the various methods of directly combining sulphur dioxide and oxygen to sulphuric acid anhydride, which latter, of course, is the basis of sulphuric acid.

All these processes are founded on the catalytic or contact action of certain bodies (contact substances), of which platinum in a finely-divided state is the most important.

The term catalytic, or contact-action, is here used in its general sense, although strictly speaking it is the property of certain bodies to assist or bring about the combination of two or more substances by means of contact *only*.

There are, however, a number of chemical processes which appear to the casual observer to be catalytic also in the above sense of the term, but in reality they are due to intermediate chemical reactions, in which certain bodies act as oxygen carriers and transmitters, thus actually taking part in the chemical reactions, but remaining unaltered at the end of the process.

Processes of this kind are termed *pseudo-catalytic*, and in this connection the Deacon process of chlorine manufacture, or, still better, the old chamber process for the manufacture of sulphuric acid, might be cited as typical examples.

The true contact action—such as is ascribed to the platinum contact substance of the sulphuric acid contact process—must, however, be classed as a physical phenomenon, since the contact substance remains unaltered all through the process.

Until recently it has been more or less generally believed that this contact action of the platinum was brought about by the well-known property of the platinum to absorb its hundred-fold volume of oxygen, thus acting as an energetic oxidiser.

Professor Erdmann, in the latest edition of his "Inorganic Chemistry," gives this as his opinion. There have, however, lately been many attempts to show that the action of the platinum is also pseudo-catalytic, and in this connection it is interesting to note, that through the investigations of Mond, Ramsay, and Shields, the existence of a platinum peroxide has been made very probable.

Engler and Wohler have actually undertaken to prove the existence of a platinum peroxide in the finely divided platinum black which acts as an oxygen carrier and transmitter. How the platinum oxide is supposed to form at the high temperatures of the contact process has not as yet been explained.

I myself am inclined to consider the catalytic action of the platinum as a "true" contact action, due to the formation of ozone in the platinum contact substance.

The formation of ozone under the prevailing circumstances is not so unlikely, since we know that ozone can be produced by compression of oxygen.

The heating of the contact substance would only tend to increase the pressure of the oxygen absorbed by the platinum, and a spontaneous formation of ozone would be quite sufficient to oxidise the sulphur dioxide.

I have not as yet sufficient data to enable me to go more fully into the details of the above theory, but hope to be able to give you more particulars at some future date.

When speaking of the pseudo-catalytic actions, the old *Chamber process* was mentioned as a typical example, and for purpose of comparison it will be interesting to follow it a little closer.

In this process nitrous acid anhydride ( $\text{N}_2\text{O}_3$ ), plays the part of the oxygen-carrier and transmitter, and readily lends part of its oxygen to oxidise the sulphur dioxide gas to sulphuric acid anhydride, which latter, in contact with water, gives the end product of the somewhat complicated reactions, namely, sulphuric acid. The de-oxidised nitrous acid anhydride, on coming into contact with the oxygen of the air, forms once more the original compound, and is again ready to transform new quantities of sulphur dioxide. Although, theoretically, an unlimited quantity of sulphuric acid could thus be produced, there are, in practice, certain unavoidable losses which add considerably to the cost of producing sulphuric acid by this method. But this is not the only disadvantage of the old process. The reactions indicated above only take place when a certain quantity of water is present, and this water dilutes the sulphuric acid obtained to such a degree that it cannot be used straight away as such, but has to be first of all concentrated.

This concentration process is very slow and costly, and the earliest attempts to work out a method which could produce sulphuric acid right away in a more concentrated form are chiefly due to this reason.

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Later on, however, it was not only the question of economy which induced the different parties concerned to continue the researches and experiments in connection with a new and better process, but the newly-established aniline-dye industry created a demand for the very strongest sulphuric acid and even anhydride, which the Austrian works of J. D. Stark, then the only producers of fuming sulphuric acid, could not meet, and which, of course, could not be obtained by the old chamber process.

It was recognised quite early that the well-known catalytic action of platinum could be used for the production of sulphuric acid anhydride, and Clemens Winkler, in "Dingler's Journal" of 1875, fully described a practical method for making sulphuric acid anhydride from sulphur dioxide and oxygen by means of the catalytic action of platinised asbestos. Curiously enough, up to that time all proposals for utilising the contact action for the making of sulphuric acid had, with only one single exception (Piria in 1855), never as their objective, the production of the anhydride itself. This was probably due to the small demand for this chemical at that time, and the consequent low price for which it could be bought. On the other hand, when Winkler first published his process for making anhydride, in 1875, he little dreamt that in a few years the contact process would be able to compete successfully with the old chamber process for making ordinary sulphuric acid.

The sole object of the inventors in the early stages of the history of the contact process was, as already indicated, the discovery of a new method for making sulphuric acid, which would do away with the disadvantages of the old chamber process, and as early as 1851 Phillips obtained a British patent for the making of sulphuric acid, which he himself describes as "an improvement in the manufacture of ordinary sulphuric acid." This patent undoubtedly contained the principal features of our modern contact process, and the catalytic action of finely divided platinum is specifically mentioned. The contact action of platinum was known to Sir Humphry Davy as early as 1817, and the very earliest inventors looked on it as the most favourable basis for a new method of sulphuric acid manufacture.

Ever since, platinum in various modifications has been exclusively used for the contact process. Iron oxide has been used for the same purpose, only very recently.

After the publication of Phillip's patent, which, as has been already pointed out, contained the principal features of the modern contact process, a great number of modifications and new processes were published by various individuals, who, up to Winkler's time, all aimed at the production of sulphuric acid alone. Petrie mentions in his English patent 590 of 1857 platinised asbestos as contact substance for the manufacture of sulphuric acid. In 1855 Piria describes the production of sul-

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phuric acid anhydride by means of platinised pumice-stone from  $\text{SO}_2$  and air, or, better still, oxygen. As early as 1852 Wohler and Mahla had found that the oxides of iron, copper, and chromium act as contact substances. Soon after, in 1853, Robb took out two English patents for the manufacture of sulphuric acid, in which he used the roasted material itself as the catalytic agent. The sulphurous gases were obtained from the roasting of pyrites, the catalytic property of the roasted material being, of course, due to the high percentage of iron oxide it contained.

The Mannheim process, to which reference has already been made, and one of the methods proposed by the Höchst Farbwerke, both of which are actually being carried on at the present time, are practically an elaboration of the above idea.

Schmersall and Bouk, in the English patent, 183, of 1885, employed heated tubes, which were filled with asbestos or mixtures of copper and chromium oxides, prepared pumice-stone, platinum, etc. The sulphurous gases were, in this process, passed through water before being allowed to combine.

In 1891 Henry Deacon tried the catalytic action of copper salts also for the manufacture of sulphuric acid anhydride and sulphuric acid. He made the very important observation that a sudden cooling of the gases after leaving the contact apparatus should be avoided, and further, that a surplus of oxygen or air should always be employed.

With the discovery of synthetical alizarine by Graebe and Liebermann in 1868, its subsequent technical manufacture in 1873, and the discovery of many more aniline dyes, which necessitated the employment of the very strongest acid and even anhydride, the contact process entered on a new phase.

The Austrian firm, L. D. Stark, which up till then had supplied all the fuming sulphuric acid, could no longer meet the increased demand, and prices went up accordingly. The demand had to be met somehow, and the contact process was the only possible means of solving the difficulty.

Winkler, as already stated, was the first to publish a method by which sulphuric acid anhydride could be obtained by the action of platinised asbestos on a mixture of  $\text{SO}_2$  and  $\text{O}$ . In his publication he already recognised the modern law of chemical mass action, according to which all admixtures of indifferent gases would be deleterious to the contact action, but, curiously enough, he, and many others after him, made the mistake of considering the superfluous oxygen as an indifferent body. Being convinced of this idea, he employed a mixture of  $\text{SO}_2$  and  $\text{O}$  in molecular proportions, obtaining it through the decomposition of ordinary sulphuric acid into its components,  $\text{SO}_2$ ,  $\text{O}$ , and  $\text{H}_2\text{O}$  by the employment of sufficient heat. After having absorbed the water, he passed the remaining mixture of sulphur dioxide and oxygen which were now, of course, in the exact proportions in which they would com-



bine to anhydride—over platinised asbestos, and thus obtained a very satisfactory amount of  $\text{SO}_3$ . The yield of about 75 per cent. which he obtained, and which was considered at the time simply marvellous, would now certainly not be considered good enough for the production of anhydride, much less, of course, for the manufacture of sulphuric acid.

Almost at the same time, in September, 1875, W. S. Squire took out an English patent for making sulphuric acid anhydride, which was practically identical with Winkler's process. He also believed that a molecular proportion of the two gases was necessary, and, just like Winkler, considered Deville's method for making oxygen by decomposing sulphuric acid at high temperature as the most suitable for this process. He employed platinised pumice-stone as contact substance, but found out that it lost its activity through the accumulation of impurities which separated out from the gases employed.

In Germany, where Winkler's process was not protected by patent, many factories started to manufacture anhydride according to his method. This process, therefore, marked a new stage in the history and further development of the contact process.

During the years that followed great efforts were made to overcome the technical difficulties of Winkler's process. The high temperature necessary for the decomposition caused a very rapid deterioration of the plant, and this was the difficulty most hard to overcome.

Dr. E. Jacob was the first to manufacture, on a large scale at Kreuznach, according to Winkler's process, and many other factories followed in quick succession. Several patents were taken out for various modifications and improvements, and of these, Squire's German patent 4285 of 1878 is perhaps of interest, inasmuch as it mentions the necessity for regulating the temperature in the contact chamber and the regeneration of heat. Dr. Majert manufactured in Schlebusch and other places according to a method which is described in his French patent, 122130, of 1878. It is interesting to learn that he even then proposed to spread the platinised asbestos on wire netting, in order to offer as little resistance as possible to the entering gases, a procedure which Knietzsch claimed as a novelty in his patent application of 1898.

The production of sulphuric acid anhydride had now become an established industry, and the monopoly of the Austrian works for fuming sulphuric acid was broken once and for all. The demand for a cheaper raw material, however, became more and more pressing, and as it was soon recognised that the molecular proportion of the two gases, such as is obtained by the decomposition of sulphuric acid by Winkler's method, was not at all essential in order to obtain good yields, a new field was thus opened to the various inventors. Winkler himself recommended in 1878 the employment of ordinary roast gases for

the contact process, and although this remained a secret for a long time, we know now that since 1879 sulphuric acid anhydride was produced from roast gases in Freiberg.

The sensitiveness of the platinum contact substance to impurities of any kind in the roast gases had also been recognised in the early stages of the contact process, but the complete purification of these gases presented great difficulties in those days. Various methods were suggested and actually employed to produce sulphurous acid in an absolutely pure state.

About this time the German chemical works at Thann entered into negotiations with Chapman, Messel and Co., of London, in order to secure the patent rights of Squire's original process, which was then being worked at Silvertown, near London. Squire, who had in the meantime left Chapman and Messel, proposed a new method of purification to the German company, which consisted in compressing the sulphur dioxide obtained by the combustion of Sicilian sulphur, and afterwards evaporating it by means of steam, when the gas obtained was naturally in a perfectly pure state. After being mixed with the theoretical quantity of air it was led through the contact ovens, which were filled with platinised asbestos. The anhydride produced was absorbed in towers, which were scrubbed with concentrated sulphuric acid. This method was adopted by the Thann factory in 1881, after many experiments and trials, and gave very satisfactory results. Chapman, Messel and Co. afterwards installed a similar plant at Silvertown.

Dr. Schroeder introduced a process much the same as this at Grillos Works, Hamborn, Germany, where liquid sulphur dioxide was being manufactured by the Schroeder-Hänisch process. As the demand for this chemical was not very great it was thought advisable to use part of it for the manufacture of anhydride, and experiments which were carried on with this object in view were so successful that in 1887 the Badische Anilin and Soda Fabrik of Ludwigshaven acquired the sole right of manufacturing anhydride by this method. But the possibility of using the cheap roast gases for the contact process was not lost sight of in the meantime. All the producers of anhydride continued experiments in this direction, and were more or less successful in obtaining the desired result. It would lead us too far to follow in detail all the interesting researches which had to be made in order to clear up the difficulties which presented themselves daily to the chemists, or to describe the great amount of skill, energy, and patience which were necessary to overcome them. Suffice it to say that various firms succeeded in working out processes, and to-day they not only supply anhydride at very low prices, but actually compete successfully with the manufacture of sulphuric acid by the chamber process. The various improvements which the individual firms introduced in the course of time were, and are, kept secret to an extent, although few, if any, really new dis-

coveries were employed in the working of the modernised process. They were really more ingenious adaptations and combinations of well-known processes, so manufacturers soon realised the difficulty of protecting their processes by patent. Consequently there were hardly any patented processes known until 1898, when the Höchster Farbwerke, Grillo, the Badische Anilin and Soda Fabrik, the Mannheim factory, and others took out a number of patents in quick succession for the manufacture of anhydride and sulphuric acid. This sudden change was brought about by the difficulty which the various firms experienced in keeping their methods secret. It was only to be expected that those still struggling with their experiments should take advantage of the hints contained in the published patents, and although this was a serious matter for the patentees, it did a great deal to advance the industry generally. As a result, there are now a great number of factories producing sulphuric acid and anhydride on a very large scale, and their special methods are covered by numerous patents. There are also some factories which still keep their methods secret, the more important among these being Chapman, Messel and Co., at Silvertown, England, the United Alkali Co., at various factories, and Tentelew's chemical factory, at St. Petersburg.

The processes at present known, or at least partially so, can be divided into two classes—those which employ platinum in some form, and those which employ other bodies as the catalytic substance.

In the first category are included the processes of the Badische Anilin and Soda Fabrik, that of the Actien Gesellschaft für Zink-Industrie at Hamborn, Winkler's process as carried on at Freiberg, and Dr. Rabe's method.

The second are represented by the Mannheim process and that of the Höchster Farbwerke.

All the above firms ranked amongst the early pioneers of the contact process, and developed their special methods more or less independently. They all recognised at some time or other the superiority of platinum over any other contact substance, the necessity for a thorough purification and drying of the gases employed, and the importance of the careful regulation of the temperature in the contact apparatus itself. However, Dr. Knietzsch, of Ludwigshaven, was the first to publish an exhaustive and valuable paper (in 1901), in which he developed the theory of the contact process under various conditions on the strength of numerous experiments and most interesting researches. He proved conclusively that the reaction can only take place quantitatively in the presence of an excess of oxygen. He further showed that the catalytic action of platinum under practical conditions starts at about  $200^{\circ}\text{C}.$  and that the velocity of the reaction increases rapidly with increasing temperatures. At  $380\text{--}400^{\circ}\text{C}.$   $\text{SO}_2$  is completely transformed into anhydride, and this state remains constant until

about 430° C. A decomposition of the anhydride already formed, takes place at temperatures above the latter point, and at about 1,000° C. no reaction whatever takes place. He also proved that the anhydride thus formed remains as such, even at fairly high temperatures, but if allowed to remain in contact with the catalytic substance it is readily decomposed at comparatively low temperatures.

From these and many other interesting experiments, which time does not permit me to detail more fully, he arrived at conclusions which have proved themselves to be of the very greatest importance for the practical working of the contact process.

The scientific world and the manufacturers of anhydride are deeply indebted to Dr. Knietzsch for the valuable information he has given them, for it has in many instances supplied the correct answer to the many whys and wherefores of the contact process.

While endeavouring to describe the actual working of the modern contact process, it will naturally be impossible to follow it in all the manifold modifications, therefore it will perhaps serve the purpose of this paper as well if only its main features are outlined, and attention drawn to any specially outstanding procedure.

Reference has already been made to the conditions which have to be observed in order to ensure a proper working of the contact process, and these are now generally recognised. With few exceptions the various manufacturers and inventors only differ in the various ways of attaining these conditions, and they naturally all claim for themselves the cheapest and most reliable method.

The modern methods of contact process, as has been seen, can be divided into two classes, and perhaps a description of the process of the Badische Fabrik will serve as an example of the first class.

This selection has been made, because, in the writer's opinion, it is the most representative and instructive of its class, and it might be remarked here that the process about to be started by the local Dynamite Factory is much the same in both principle and practice.

The Badische Soda Fabrik lays particular stress on "the preliminary treatment of the gas-mixtures to be operated on, on the regulation of the conditions—particularly as to the temperature under which the combination of the gases takes place—and on a peculiar arrangement of the contact-substance in the apparatus, for the purpose of obtaining therefrom the most advantageous effects."

The preliminary treatment consists of thoroughly mixing the gas mixture, washing it, and finally re-drying it.

The mixing of the gases has for its object the burning of

all sublimed sulphur which might be present, and which is very harmful as a carrier of impurities.

This is effected by a jet of steam, which, on condensing, afterwards serves to dilute the small quantities of sulphuric acid which separate from the gases on their way to the washing apparatus. The mixed gases, after having been gradually cooled in a special cooling apparatus, are then subjected to a washing process, where they are purified completely and freed from all injurious admixtures.

The washing is effected by means of water or diluted sulphuric acid in scrubbers, and special chemical and optical tests are employed to make certain that no injurious admixtures are present. The gases are next dried over concentrated sulphuric acid, and after having been heated to a suitable temperature are led into the contact apparatus. In this, the contact substance (platinised asbestos) is spread out on sieves, which are so arranged that each one supports the sieve immediately above it. The gases thus find little or no resistance in passing through the apparatus, and ordinary rotating fans are sufficient to suck them through the whole system.

The contact apparatus has, further, special heating and cooling appliances, by which the temperature of the contact chamber is regulated. The cooling arrangements form a special feature of this process.

The excessive heat, which is the result of the reaction, is utilised for the pre-heating of the roast gases before they are admitted into the contact chamber. As the greatest amount of heat is liberated, where the gases first meet the contact substance, and an overheating is most likely to occur at this place, provision is made for the cooling gases to enter the jacket which surrounds the contact chamber at this point. The temperature of all parts of the apparatus is, of course, closely watched by means of pyrometers, and regulated accordingly.

The anhydride produced is afterwards absorbed by strong sulphuric acid, in which it readily dissolves.

The Badische Fabrik claims to obtain with this process a yield of 96 to 98 per cent., and this is certainly very satisfactory.

The principal feature of Winkler's process is the filtration of the roast gases. He does not employ a washing process for their purification, considering a simple filtration through wool and wood shavings sufficient. As in the Rabe method, he does not aim at a complete conversion of the  $\text{SO}_2$  into anhydride, and leads the unconverted sulphur-dioxide to ordinary sulphuric acid chambers.

Grillo's process is more akin to that of the Badische Fabrik, but differs from it principally in the methods employed for purifying the gases and in the disposition of the contact-substance. This latter is in a compressed state, and as a result offers so much resistance to the passage of the gases that com-

pressors are employed for the purpose of moving them through the system. The inventors, however, maintain that this slight compression is very advantageous, insomuch as it brings the gas-particles closer together, thus insuring a better conversion.

The second category of processes still remains to be considered, and, as will be remembered, they are concerned with the catalytic effect produced by bodies other than platinum. Perhaps the Mannheim process is the most interesting of this class. By it, the conversion of sulphur-dioxide into anhydride is effected in two separate stages, and many of the conclusions at which Dr. Knietzsch arrived as a result of his elaborate researches, published in 1901, were employed in the Mannheim process on a working scale as early as 1898. The first stage of the conversion is effected by the catalytic action of oxide of iron. Only a part of the sulphur-dioxide is converted into anhydride at this stage, and the remainder is catalysed by passing over platinum in the usual manner. The process seems to give very satisfactory results.

It is essential that the roast gases should be absolutely dry, so the air used for roasting the pyrites is dried with sulphuric acid. The dry roast gases are first of all passed up a tower filled with iron oxide, where 60 to 65 per cent. of the sulphur-dioxide is converted into anhydride. The arsenic contained in the roast gases is at the same time chemically fixed by the iron oxide, and thus effectively removed, and it is interesting to note that the arseniate of iron improves the catalytic action of the oxide.

The gases next pass into a cooling apparatus, when all the anhydride formed condenses. The unconverted portion of the gases passes on, is filtered through loose and porous bodies, and, after having been heated to the required temperature, is next passed over the contact substance, which is contained in a second chamber, where the final conversion takes place. The next stage in the process is the passing of the gases through another cooling apparatus, and finally through an absorption plant, when the anhydride formed in the second stage of the process is retained.

The Farbwerke at Hoechst, which was one of the first to produce anhydride and sulphuric acid by the contact process, has lately taken patents for another method. In this they employ roasted pyrites, which are impregnated with iron sulphate, for effecting the conversion of the  $\text{SO}_2$  of the roast-gases employed into anhydride.

The iron sulphate decomposes at the high temperatures into iron oxide, sulphuric acid, and anhydride, and this newly-formed iron oxide has in addition a very energetic catalytic action readily acting on the sulphur-dioxide of the roast-gases. The reaction takes place in a long channel. At the one end the impregnated roasted material is being continually introduced, and meets the roast-gases coming from the opposite direction.

This method seems also to give very satisfactory results. It is at present carried out in the Höchster Farbwerke itself, as also in Hamburg and Hruschau.

This very brief outline of the contact process has, I am aware, been very superficial, but the main principles have been referred to. The subject is so vast that it is impossible to do more within the limits of an ordinary paper, but on a future occasion it may be my privilege to revert again to the subject.



## 9.—SOME ECONOMIC PROBLEMS IN METALLURGY ON THE WITWATERSRAND.

BY HARRY S. DENNY.

In these notes I propose to deal briefly with the main operations of present practice, and with some of the points where, contingent upon the settlement of certain problems now confronting us, material improvements appear to be both possible and probable.

The metallurgist on these fields has not to deal with anything in the nature of a highly refractory ore, and his operations, therefore, are not interfered with by complex chemical difficulties at any point. Despite this fact, however, and even admitting that each of the problems before us is more or less of a simple nature from a metallurgical point of view, we find that the factor of economy is so interwoven with the more scientific aspect at every point that our problems demand the most careful investigation for their determination and solution, particularly in view of their bearing on the general advancement that is being witnessed from year to year.

From the preliminary breaking of our ores to the handling of the final residues a remarkable amount of care has been devoted to every important function of our various processes, particularly in the past 10 years, and in each of the operations, as conducted here, there is no doubt that we have the embodiment of nearly all that practical science knows in those directions to-day.

I propose to briefly touch upon the more important of these operations for the purpose of indicating what the precise nature of some of the problems connected with them is, and finally I shall endeavour to indicate what effect the successful settlement of some of these problems may have upon our metallurgical schemes of to-day.

### PRELIMINARY BREAKING.

The necessity for preliminary breaking is dependent upon two factors:—

1. The spacing of the bars over the ore bins in the mine.
2. The spacing of the grizzly bars in the headgear.

Depending upon these two factors we have a certain size and quantity of ore, which will not pass through the grizzlies in the headgear, and if amongst these we have to deal with blocks up to 10 in. in diameter, it is usual to select such pieces and submit them to a preliminary hand breaking for the separation of any pieces of reef from waste rock, or for the purpose of reducing the size to a point suitable for the second crushing which ensues after sorting.

The practice is generally tending towards reducing the space between the bars over the ore bins in the mine, so that the preliminary breaking by hammer may be done underground, but in every mine will be found some variation in the particular manner in which the ore breaks, and the bars



should be so placed as to meet the requirements of each, and in such a way as to ensure that there will not be a large percentage of big pieces of ore passing over the grizzlies in the headgear. The bars in the headgear grizzlies are so placed as to effect the separation of the fines from the coarser rock, and if the spacing is too limited choking on the bars will ensue, whilst, on the contrary, if too wide too much coarse rock passes through with the fines. For each mine the particular limit suiting the ore must be determined.

The object of the separation on the grizzlies is twofold, being, firstly, to leave the coarse rock so clean that, after wetting, reef matter may be easily separated from waste rock, and, secondly, that the coarse rock may be subjected to a further reduction in crushers without necessitating the passing of all the original fines through crushers also.

If a large percentage of sorting is to be done, that is to say, if the reefs mined are very narrow and the bulk of the ore consists of waste, and if the reef matter has a tendency to adhere to the country rock on the footwall and hanging wall sides, then to obtain a high percentage sorting it is necessary to reduce the coarse rock passing over the grizzlies to something in the neighbourhood of, say, 3 in. cubes. Where there is not such a large proportion of waste, and where the other difficulties mentioned do not obtain, the preliminary crushing need not be carried to so fine a point.

#### SORTING.

The object of sorting is to discard rock of no value in order to avoid the cost of handling it in the subsequent treatment operations and the value of limitations of the operation are contingent entirely upon the working costs obtaining on the particular mine concerned, *i.e.*, it will be economical only to discard rock of a value which would not show a profit in those other operations referred to. On each mine this is a particularly close calculation, as to do a too low percentage of sorting in order to be sure that the discarded rock is valueless may leave a certain percentage of waste rock in the ore, which is afterwards treated at a loss; whilst, on the contrary, to carry the operation to too high a point may again result in loss by virtue of discarding rock of an average value that would yield a small profit by treatment.

Again we have a point that for its determination requires the most careful handling, and one that on each particular mine must be figured out to suit all the other conditions.

The difficulties that immediately confront one in this problem are:—

1. To ascertain accurately the value of the discarded rock; and
2. To figure exactly what limit of value must pertain to the ore to ensure profitable treatment in the subsequent operations.

Many suggestions have been made regarding the first point, but no recognised or efficient method has yet been adopted generally on these fields; whilst regarding the second point, to my mind, there are many factors that have to be taken into consideration which are generally neglected. For instance, we assume that on 10 dwt. rock an 85 per cent. extraction is obtainable, but it does not follow that on 2 dwt. rock the same result can be obtained.

Again, we have to consider that every ton of waste rock that comes into the mill becomes enriched as sands residues, slimes, or slimes residues; and thirdly there is the factor of increased consumption of water with its concomitant increased pumping charges, loss of water, up-keep of dams, etc.

It will be seen from the above that to figure exactly on the limitations of sorting is a particularly nice calculation, and in my opinion one that has so far been treated more in a general than in a detailed fashion, and one, further, that requires ventilation.

#### CRUSHING.

After sorting the ore is passed through further breakers, and reduced to something in the neighbourhood of  $1\frac{1}{2}$  in. to 2 in. cubes.

Again, we are confronted with the question whether it would not be more economical to design our crushers to reduce the whole of the ore to the size of peas, or say  $\frac{1}{4}$  in. cubes.

The problem we have to determine may be stated as the cost of breaking ore by the ordinary gyratory or toggle movement of a crusher as compared with the cost of direct percussion, such as obtains in a stamp mill.

There is no doubt that the capacity of a stamp mill would be much higher per stamp per day on  $\frac{1}{4}$  in. cubes than on  $1\frac{1}{2}$  in. cubes, but against this increased capacity we have to set the cost of reducing in crushers to the lower of these limits. The correct determination of this point would ensure the maximum efficiency from both our crushers and our stamps, but the line of demarcation has yet to be accurately determined. It would appear, however, that as the churning tendency of a stamp mill does not appear in a crusher—or, in other words, that whereas we can obtain positive clearance in a crusher, we cannot do so in a stamp mill—the reduction to comparatively low limits in our crushers would prove the more economical operation.

#### MILLING.

In the stamp mills of a battery the ore is reduced to various finenesses, ranging from 300 to 1,000 holes to the square inch, and practice on this point has so far been guided by the extraction obtained in the operations of sands treatment and slimes treatment. The point arises, however, as to where the full virtue of crushing with a mill ceases: that is to say, whether it would not be more profitable to use a mesh of 100 holes to the square inch with the object of further

reducing in a separate plant, or whether we should generally adopt, say, 1,000 holes to the square inch.

Experience has shown that after a certain point has been reached—say to 300 holes to the square inch—that the further reduction from that point to 1,000 holes to the square inch is more economically and easily done by attrition than by percussion, and again we are confronted with the fact that the churning action in the mill tends to retard clearance, whilst in a proper attrition mill, such as a flint mill, clearance becomes more positive.

On general principles, therefore, in my opinion, it may be accepted as an axiom that sliming can be more economically done on the principle of attrition than percussion, and we are therefore called upon to determine the precise point where the virtue of milling ceases and that of attrition begins. So far this point has not been settled, and, as before remarked, practice has been guided in the alteration of the mesh employed by the results obtained from the ensuing operations.

#### AMALGAMATION.

From the mill the crushed pulp is passed over amalgamated copper plates, and on an average on these fields between 60 per cent. and 70 per cent. of the total recovery has been extracted by this operation.

There is very little variation in the method of erecting plates and working them. There are slight differences in the amount of mercury used, and the manner and time of dressing the plates, and so on; but, in general, practice on this point may be taken as fairly uniform.

In the past 20 years many attempts have been made to improve amalgamation by using amalgamated drums, mercury riffles, etc., but no radical alterations have been adopted.

In view of the fact that there are certain vital differences in the physical constitution of the Witwatersrand Banket Ores it would appear only natural to assume that to obtain the highest extraction by amalgamation certain innovations on general practice would be found necessary; and in view of the further fact that it is by this operation that the bulk of our gold is extracted, I think that something should be done in the matter of determining whether some improvement or alteration to meet differences in ore constitution could not be made. It is hardly reasonable to suppose that we have reached perfection in amalgamation methods, and although I find it difficult to suggest anything in the way of an alteration that could be considered as constituting a radical change, I still have the feeling that we should know more about the application of this operation to our various ores than we do to-day.

It must not be forgotten in this connection that amalgamation is the least expensive operation—in relation to the gold that it accounts for—that we to-day employ, and it therefore

becomes incumbent upon us to bring our practice on this particular point to the highest possible efficiency.

There is no doubt that the mesh employed in the mill has a very direct bearing on the amount of gold caught on our plates, and following on this it may be further stated that within reasonable limits the finer the mesh the greater the efficiency of amalgamation.

It would appear, therefore, that fine grinding gains one important advantage, even at this stage, over coarse grinding, and this fact must not be overlooked when the cost of fine grinding is being taken into consideration.

It has been suggested by many writers that if a coarse mesh is used on the mill, the pulp after passing over the plates should be classified into fine pulp, capable of passing through a mesh of 100 holes to the linear inch, and that the balance, consisting of coarser fragments, should be returned to the mill. The percentage of slimes separated in this way varies very considerably on different mines, and, expressed in figures, employing a 600 mesh, it might be put approximately at from 40 per cent. to 60 per cent., and the amount returned to the mill would therefore vary in this ratio, and the capacity of the mill would equally vary.

As before stated, it is most important to get the highest possible extraction by amalgamation, and if by finer grinding the extraction can be improved, we are faced with a problem the solution of which will determine the limitations of fine grinding.

As the operations of cyaniding and sliming are conducted to-day the question of fine grinding has an important bearing, and on most mines the operation of milling is conducted to produce as small an amount of slimes as possible, as the subsequent settlement of the sands and the leaching product provided by that settlement is directly influenced by the amount of slime in the pulp: that is to say, if the whole of the ore was slimed to a point where it would all pass through a mesh of, say, 200 holes to the linear inch, then our present sands treatment could not be practised. The points therefore are:—

1. To what extent could we increase our extraction by amalgamation by fine grinding?
2. To what extent do we depreciate the value of our sands treatment on the same score? And,
3. Assuming that we slime everything, and we treat the pulp after leaving the plates as a slime, would results on that basis show a higher extraction on the combined operations of amalgamation and slimes treatment, than at present obtained on amalgamation, sands treatment, and slimes treatment.

Into this consideration enter many factors of importance, which may be stated as follows:—

1. Is there any known method for the treatment of such

slimes which has operated successfully over a given period?

2. Does that operation entail further capital expenditure in the way of plant, or further working costs in operation?
3. Could we safely calculate to get the same extraction from the whole of the pulp treated as slimes as we do from the slimes plant in operation on the Rand to-day?

In reply to these questions, we have not, as far as these fields are concerned, any evidence which entirely fulfills the requirements of a complete reply, but we have certain evidence in the way of experiments conducted on a fairly large scale on these fields, and we have data obtained from other fields where sliming is resorted to, which would imply that there are possibilities embodied in the queries which are worthy of the most minute investigation.

If it be decided that the whole of the pulp should be slimed, we have before us sufficient evidence to-day to convince ourselves that such equipment as would be required for the operation is available. I refer specifically here to the Flint Mills working in Western Australia, duplicates of which have already been introduced on these fields for purposes of experiment.

We are not in a position to say what the cost of that sliming would be, and that can only be proved by experiment on a practical scale. The possibilities, however, involved in the suggestion have an enormous bearing on the future of these fields, but before enlarging on this point further I shall deal with the other sections of our operations.

#### CONCENTRATION.

In the matter of concentration, we have three methods in operation to-day, which may be described as follows:—

1. An ordinary settling box is placed between the overflow from the amalgamated plates and the settling tanks, and the full flow from the launder passes into this box, and a rough classification of the heavier product in the pulp is made.
2. The pulp from the plates passes through a series of Spitzluten varying in size and number, the product from which is continuously discharged into separate treatment vats.
3. The pulp after leaving the plates passes over Frue vanners, Wilfley Tables, or other mechanical concentrating device, and the product in some cases is sold to chemical works, whilst in others it is treated on the mine by roasting and chlorination, or other suitable treatment.

There is no question that in the Witwatersrand ores the gold in the pyritic content offers itself more readily to extrac-

tion in one case as compared with others. Hence we find that on some mines, although the pyritic content of the ore is rich in gold, a high extraction is obtained from it in the ordinary cyanide process for the treatment of sands, whilst in others only a very low percentage yield can be obtained by that method. Hence several of the mines are compelled to resort to one or other of the forms of concentration above specified. In some cases the first method, with subsequent cyanide treatment, yields fairly satisfactory results, and the expenditure with this method is low.

The second method provides a cleaner concentrate than the first, and the cost of treatment by the ordinary cyanide process is moderately high.

The third method gives a product containing relatively a high percentage extraction to the ordinary cyanide process. With this class of concentrate roasting and chlorination is in most cases adopted, but when the original cost of mechanical concentration, with the subsequent cost of roasting and chlorination is figured out, it is found to be a highly expensive procedure.

It has been established clearly by experiment that these concentrates, if ground fine enough to pass through a mesh of 200 holes to the linear inch, yield a very high percentage of their gold content to a simple method of agitation in the presence of air in cyanide solution, the time of treatment being very short. On one mine on these fields a plant is now being erected to take the whole of the concentrates made by Fruevanners, grind them fine in a Flint Mill, and treat them by cyanide in the presence of air as above suggested.

The cost of the concentration alone, however, is such a heavy charge on these concentrates that the question arises whether, in a case where the whole of the pulp has to be slimed, better results would not be obtained without resorting to concentration at all. It has been conclusively proved that both from concentrates and slimes a high extraction can be obtained in a very short treatment if the charge be agitated in cyanide solution in the presence of air, but the same proof has not been forthcoming in the matter of finely-ground sands as from concentrates and slimes, and having finally proved this point, the way becomes clear for an alteration in our whole present scheme of the treatment of sands, concentrates and slimes.

The tendency on these fields to-day is to neglect the question of concentration by mechanical means. It would be interesting, however, before deciding that such a step is the correct one, to take the residues from sands treatment and the residues from slimes treatment on all the mines on the fields, and by extracting from these their pyritic content, ascertain finally what amount of gold is still left in the concentrates; and to my mind it would be clearly shown that there are some



instances where concentration under present conditions would show better results than are being obtained. In my opinion this is information that should be regularly recorded on every mine.

In the matter of slimes treatment a good deal has been done in the past 10 years, but in view of the fact that current slimes will readily yield their gold in a high percentage when treated by a continuous agitation method, I think there is room for improvement in practice to-day.

The problem that confronts us in this case is, after the treatment of the slimes by agitation, to economically and expeditiously separate the solution from the settled slimes, and to leave not more than, say, from 10 per cent. to 15 per cent. of moisture in the final residues—preferably less. The present practice is to first settle the slimes and decant all the clear water, then add cyanide solution and pump the whole of the mixture into treatment tanks, and circulate from one tank to another by pumping; then settle further and draw off the solution containing the gold, and then wash the remaining slimes one or more times, settle between each operation, and draw off the clear liquid, and finally discharge the residues containing some 40 per cent. to 50 per cent. of moisture.

It has been clearly proved in other countries that by filter pressing the separation of the slimes and contained water can be very efficiently carried out.

The problem here is to find out to what extent filter pressing could be worked on our slimes residues, taking into careful consideration the cost of the operation, and further to so arrange our plants that the necessary agitation can be obtained without resorting to settling, pumping, and decantation methods now in vogue.

The settlement of these problems should give us a plant costing us considerably less in initial outlay, and one which could be operated at a much lower cost per ton.

It has already been pointed out by various metallurgists that we may find it advantageous at some future date to carry out the operation of amalgamation quite apart from milling.

If it is possible to treat our pulp in one operation, as suggested in these notes, it would not be difficult to arrange that the amalgamation be carried out under the same roof as the treatment of slimes product, and one metallurgist would therefore control the whole of the treatment of the pulp, whilst the mill would be run by engineers.

Finally, the object of our investigations is, by combining our treatment of concentrates, sands, and slimes into one operation to obtain:—

1. Decreased initial outlay on equipment.
2. Decreased maintenance on plant.
3. Less labour required.
4. Less handling of residues.

5. Considerably lower working costs. And
6. Considerably increased profits per ton.

The matter of increased extraction is obviously a consideration of the highest importance, but, admitting that there were no improvement on this score, the other advantages mentioned would represent very material advances, which might be expressed as:—

1. Larger dividends.
2. Lower grade mines now lying idle as unpayable coming within the margin of profit-earners.

The importance of these two last factors to the industry, the community, and the country at large, cannot be overlooked, and in view of such a statement the efforts of the whole industry should be constantly directed towards accomplishing the ends at which we are aiming.

In concluding my remarks I should like to mention that there are many points of detail which call for attention that I have not touched upon, preferring rather to deal only with those which appear to me of the most vital importance to-day.

To summarise, we have the following points for determination:—

1. The limitations of Preliminary Breaking.
2. The limitations of Sorting.
3. The limitations of Crushing.
4. The limitations of Milling.
5. The limitations of Fine grinding by attrition.
6. The limitations of Amalgamation.
7. The limitations of Slimes Treatment.
8. The limitations of Concentration and the Treatment of Concentrates.
9. The limitations of Filter Pressing.
10. The limitations of Extraction.

By the solution of these problems we hope to arrive at:—

1. Simplified operations.
2. Reduced number of operations.
3. Combined Treatment of Concentrates, Slimes, and Sands.
4. Increased Extraction.
5. Lower Working Costs.
6. Reduced Capital Expenditure.
7. Increased Dividends.
8. Profitable treatment of low grade ores.

NOTE.—In July, 1903, the writer dealt with some of the points mentioned in the foregoing paper, and produced certain evidence in the way of figures, experiments, etc., in support of his contentions. The present paper has been framed on the assumption that the figures given in the previous paper have been accepted (See "Observations on the Metallurgical Practice of the Witwatersrand." Journ. Chem. Met. Soc. S. Afr., Vol. IV. No. I., Johannesburg, July, 1903.)



## 10.—THE BLIZZARD OF JUNE 9th-12th, 1902.

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CAPE COLONY.

[*Abstract.*]

(Plates V. & VI.)

Seldom has South Africa been visited by a snowstorm of such severity, duration, and extent as that which started approximately at 6 p.m. on the evening of the 9th of June, 1902, and continued practically without intermission at many places till the morning of the 12th. On plotting the stations at which snow was reported to have fallen, it is found that it covered a very large area (See Pl. V.), limited on the east by the Drakensberg Range, bordering Natal—from Charleston to Richmond and Ixopo—thence along the spurs of that range by Kokstad, Maclear, Barkly East, Dordrecht, south to Dohne, then eastwards to Fort Fordyce, and along the Winterberg to the neighbourhood of Cradock. No snow, however, seems to have fallen either at Cradock or over that plateau of the Northern Karroo, of which it forms the southern entrance, so that the boundary of the snow area then turns northwards through Tarkastad, thence north-west to Maraisburg; it then runs in a westerly direction through Tafelberg Hall to the Sneeuwberg Range to the north of Graaff-Reinet; here the boundary seems to have extended south-eastwards along the Zwagershoek Mountains to Somerset East. Westwards, it extended as a narrow belt through De Kruis (Middelburg) to Wagenaar's Kraal. From De Kruis (Murraysburg) the boundary runs in a northerly direction to De Aar, and thence north-eastwards—some distance to the west of the railway—at least as far as Kroonstad. It will thus be seen that the storm took place chiefly along the upper parts of the Orange River, the falls of snow being heaviest about Kokstad, Basutoland, and the neighbourhood of Barkly East and Aliwal North and in the railway cutting between Naauwpoort and Carlton. The snow seems to have died out a little to the west of the railway line in the Orange River Colony, although it was again reported by observers at stations near the Kaap Plateau, from New Year's Kraal, northwards through Griquatown to Newlands, in Barkly West; while snow also fell in small quantities at Douglas, Hope Town, Zeekoegat in the Britstown Division, and Biesjesdam in Victoria West. Outside of this central area snow and sleet fell at Zwartberg Pass for four days (9th-12th), also as far south as Concordia (Knysna), on the Outeniqua Mountains, and the Piquetberg Mountains. Most peculiarly it was reported as lying on the Palmiet River Flats in the Caledon Division, while the snow lay on the face of Table Mountain on the morning of the 10th to a lower elevation than has occurred before. It may be noted that it is a comparatively rare occur-

rence for snow to be seen on Table Mountain, as between 1860 and 1903 only seven instances have been noted—viz., 2nd September, 1860; 17th July, 1862; 12th September, 1864; 22nd August, 1869; 24th May, 1895; 10th June, 1902; and the 17th August, 1903. The amount of damage done has not been ascertained, but quite a large number of lives were lost, and thousands of cattle and sheep died, not so much from the snowstorm itself as from the intense and prolonged frosts which succeeded this blizzard. Although the maximum fall of snow seems to have been equivalent to about  $3\frac{1}{2}$  in. of rain, the exceptionally strong south-east and subsequent south-west winds collected the snow into drifts, in some cases 20 feet deep, rendering communication with many places, especially in Kaffraria, impossible. During this period the rainfall was extremely heavy over large areas in the east, (see Pl. VI.), the maxima being 9.25 in. in 22 hours at Flagstaff between 8 a.m. on the 11th and 6 a.m. on the 12th, and 8.06 in. at Port St. John's in 23 hours on the same dates. Judging from the barometric readings, this storm seems to have originated in an area of low pressure in the north of the Colony, while the pressure in the west and south was increasing rapidly, after the passage of a depression south of our coasts.

The area of the snowfall seems to have been even more extensive than is indicated above, for, as the following translation from the "Meteorologische Zeitschrift" of March, 1904 (p. 147), the original of which was kindly supplied by Mr. R. T. A. Innes, Director of the Transvaal Meteorological Service, shows, it extended over German South-West Africa:—

"As an abnormal weather condition, we ought particularly  
 "to mention the snowfall and intense frost, which occurred on  
 "the 10th to 11th June, 1902. The snow was specially noted in  
 "the central and southerly portions of the Protectorate, while  
 "the northern and extreme southern parts seem to have been  
 "exempt. It apparently occurred almost simultaneously over  
 "the affected area. From Hoachanas<sup>1</sup> particularly is reported:  
 "'On the 10th June, 4 p.m., snow 10 centimeters (3.9 inches)  
 "'deep, which continued to lie on shady places having a south-  
 "'erly aspect, till the 12th.'

"It is interesting to find that about the same time a snow-  
 "storm occurred in the Transvaal and the Cape Colony, which  
 "was so severe as to cause the stoppage of railway trains. As  
 "the result of inquiries, it has been ascertained that snow fell  
 "in the neighbourhood of Windhoek in the years 1891 and 1892  
 "only. In the cold period of the year 1902, particularly low  
 "temperatures were observed, thus the temperature at Wind-  
 "hoek<sup>2</sup> seems to have fallen to  $-8^{\circ}$  and  $-9^{\circ}$  Cent. in June  
 "(i.e.,  $17.6^{\circ}$  to  $15.8^{\circ}$  Fahr.). According to the views of

<sup>1</sup> Approximate position of Hoachanas. Lat.  $23^{\circ} 57' S.$ ; Long.  $17^{\circ} 58' E.$ ; Height, 4,300 feet.

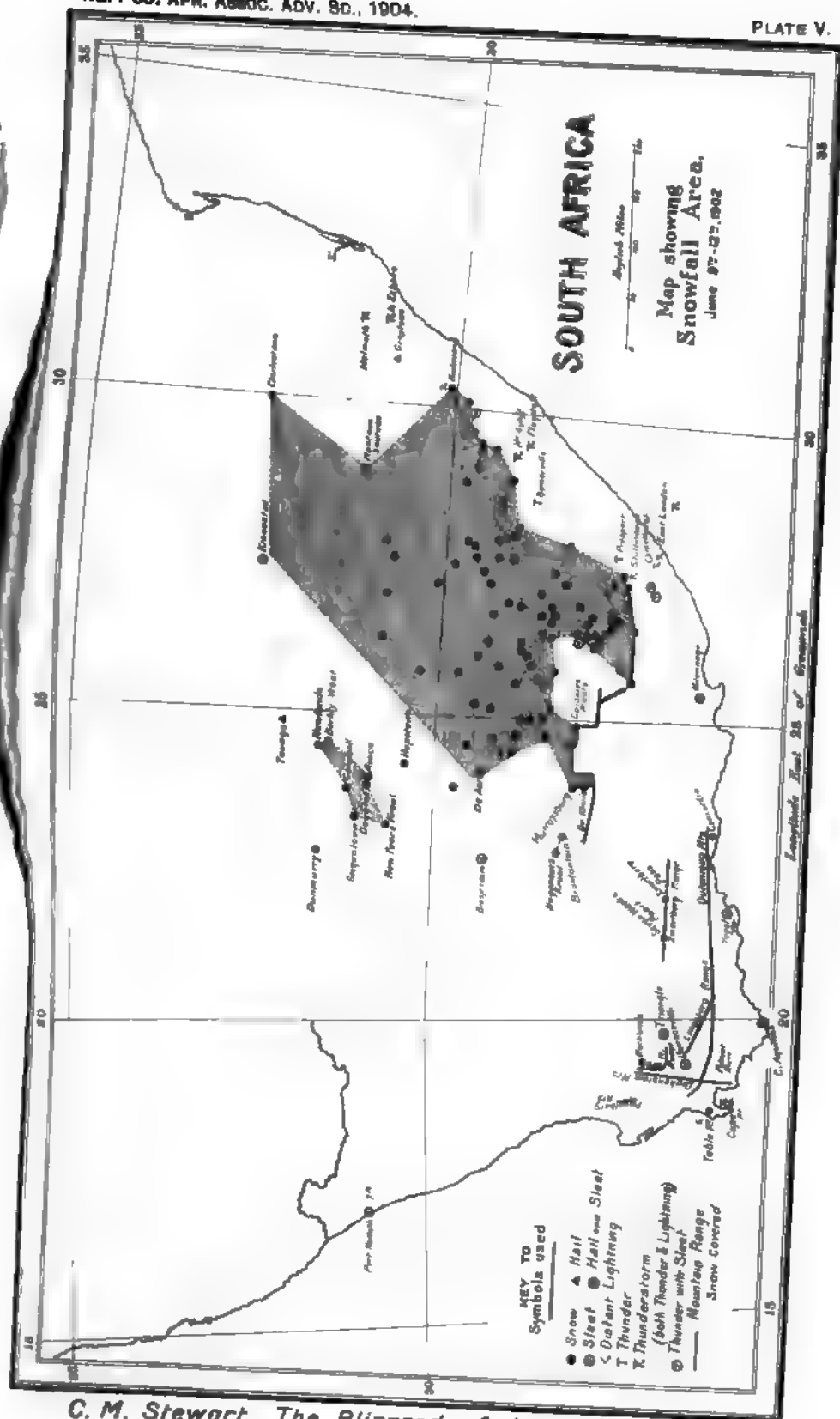
<sup>2</sup> Lat.  $22^{\circ} 30' S.$ ; Long.  $17^{\circ} 6' E.$ ; Height, 5,315 feet.

“the older Colonists, after such abnormal phenomena—snow  
“and intense cold—a series of rainy years formerly ensued, an  
“opinion the confirmation of which is much to be desired.”

#### EXPLANATION OF PLATES.

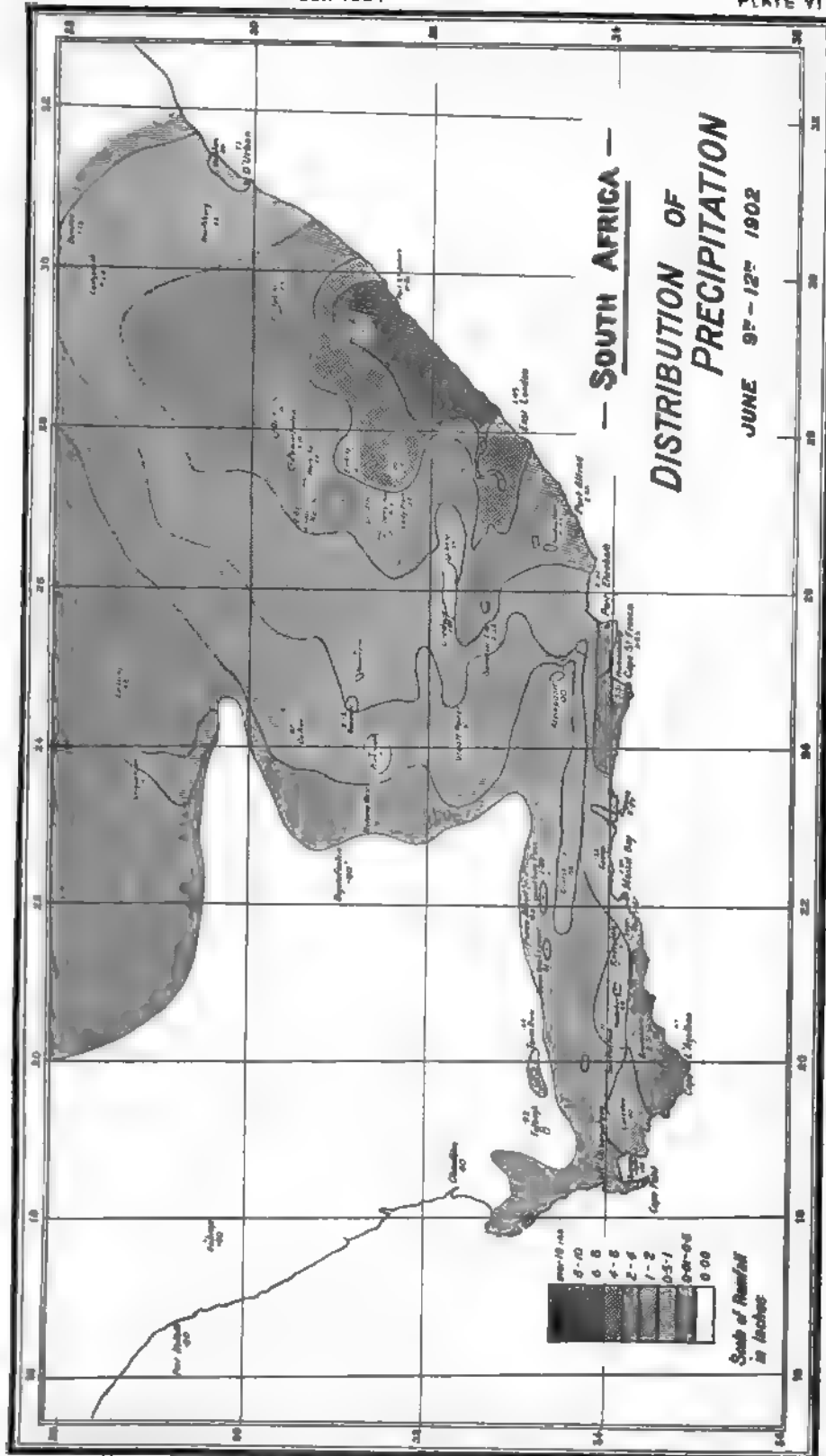
PLATE V. shows the area over which snow, irrespective of quantity, was reported to have fallen on one or more days during the period June 9th—12th. The continuous lines ——— represent the mountain ranges on which snow was reported to be lying; while the portions bounded by broken lines ( - - - - - ) represent the continuous areas over which snow fell. A comparison of this map with one giving contour lines, shows that the snow-area closely followed the 3,500 ft. contour.

PLATE VI. shows approximately the distribution of precipitation during the period June 9th—12th, in terms of inches of rain; the amount of the precipitation increases with the intensity of the shading, those areas having approximately equal amounts of rainfall being bounded by continuous lines (Isohyets or lines of equal rainfall). This map taken in conjunction with Pl. V. will give a good idea of the areas over which the snowfall was heaviest.



C. M. Stewart. The Blizzard of June 9-12, 1902.





*C.M. Stewart: The Blizzard of June 9-12, 1902.*

Instrument.	Evaporating Surface.	Area of Surface.	Relative Evaporation.	Reduction Factor.
Wild ... ..	Free Water Surface	38.0 sq. in.	26.5	1.000
Lamont ... ..	Do.	7.6 „	43.6	.595
De la Rue ... ..	Wet Parchment Paper	19.5 „	32.	.820
Piche ... ..	Wet Filter Paper	1.7 „	54.8	.485

Shaw's final conclusions are :—" The area of the evaporating surface appears to be the main cause of the very great differences between the indications of the different instruments. . . . . The evaporation is less as the area exposed to evaporation becomes greater. . . . . This, however, though accounting for the larger part of the differences, does not give by any means a complete explanation. The difficulties pointed out in describing the working of the different instruments give rise, doubtless, to errors that can at present only be classed as accidental, and, moreover, in case the temperature of the air changes, we shall probably have the evaporating water at different temperatures in the different instruments. . . . . The observations show plainly that the amount of water evaporated from any surface of water depends upon so many conditions besides those determined by the state of the air, that very little meteorological information can be obtained from them until the effect of these secondary conditions can be measured and allowed for."

Comparative ratios of evaporation from the three Kenilworth instruments are :—

		Night.	Day.	Total.
Piche	...	27.76	72.24	100.00
Tub	...	33.81	66.19	100.00
Tank	...	32.19	67.81	100.00

In summer there is an approach to equality in all three gauges, but in winter the Tank evaporates much less than the Tub, and still less than the Piche Tube. Comparative percentages according to season are :—

	Jan	Mar.	April - June.	July --Sept.	October—Dec.
Piche ... ..	27.19	16.15	22.37	34.29	
Tub ... ..	29.43	14.29	19.28	37.00	
Tank ... ..	32.82	12.47	15.63	39.08	

<sup>1</sup> W. N. Shaw, "Report on Evaporimeters," 1884. It is to be noted that Stefan makes the quantity of evaporation depend upon the diameter, and not upon the area of a circular evaporating vessel.

It appears from these results that it is not possible to reduce the indications of one evaporimeter to those of another by means of any simple factor.

Approximate formulae for the daily averages, counting from the middle of January, are:—

$$\begin{aligned} \text{PICHE.} \quad E = & .23 + .088 \sin (n30^\circ + 131^\circ) \\ & + .006 \sin (n60^\circ + 196^\circ) \\ & + \dots\dots\dots (1) \end{aligned}$$

$$\begin{aligned} \text{TUB.} \quad E = & .18 + .099 \sin (n30^\circ + 128^\circ) \\ & + .012 \sin (n60^\circ + 172^\circ) \\ & + \dots\dots\dots (2) \end{aligned}$$

$$\begin{aligned} \text{TANK.} \quad E = & .16 + .113 \sin (n30^\circ + 116^\circ) \\ & + .012 \sin (n60^\circ + 164^\circ) \\ & + \dots\dots\dots (3) \end{aligned}$$

None of these terms agree with the corresponding terms for temperature. The epochs of the first harmonic terms are earlier than the first harmonic terms of maximum temperature, and still earlier than those of mean temperature. For each gauge the epoch of the first harmonic term of evaporation falls, indeed, between the beginning and end of December, whereas the temperature epoch comes at the end of the same month.<sup>1</sup> Since October and November are considerably drier than January and February, it seems that the influence of the decreased humidity in the spring is here apparent.

These harmonic formulae are worked out on the assumption that each month is one-twelfth of a year. Since the months vary in length, this will displace the epochs somewhat, particularly in the terms after the third. No useful purpose, however, seems likely to be attained by dividing the year accurately into aliquot parts, for probably the diurnal variation would introduce errors equally serious. Bessel, in discussing the Königsberg temperatures, divided the year into 73 periods of 5.00332 days, or in angular measure 4 deg. 55 min. 53.425 sec. each, and computed the formula as far as the fourth harmonic term!<sup>2</sup> The labour entailed was, of course, enormous, and not apparently very fruitful.<sup>3</sup>

In Table 2 will be found a tabular scheme of horary values of all the meteorological elements which seem likely to be of importance in influencing the evaporation. With the idea of making the numbers more comparable, the total ranges from greatest to least have in every case been expressed in parts of a thousand, and shown in the columns headed "rise from minimum," or "fall from maximum." The last two columns have been computed by means of Fitz-Gerald's formula: they will be referred to again later on. All the maxima are in heavy type: the minima are in italics.

It is evident that the evaporation is most rapid nearly half-an-hour earlier than the time when the air is hottest and

<sup>1</sup> See "Some Results derived from the Constant Values in the Periodic Formulae." *Transactions S. 4. Phil. Soc.*, Vol. XIV., Part 2., p. 113.

<sup>2</sup> *Q. W. R.* Part IV., 1870.

<sup>3</sup> See, however, Hann, *Lehrbuch*, p. 735.



driest. From which it appears that the earlier maximum wind velocity has greater influence than the later minimum of vapour tension. A curious fact is that the minimum of evaporation comes earlier than the minimum of any other element: indeed the evaporation is rapidly increasing while the temperature of the air is still falling, and its relative humidity still rising. We are referring here, of course, to annual means and totals. It seems probable that the rate of increase after sunrise in the more vigorous summer evaporation is sufficient to impress itself upon the annual averages. This does not agree with the Cairo results, in which temperature and evaporation taken at intervals of two hours, "have exactly the same daily period," winter and summer.<sup>1</sup>

The hourly totals of evaporation from the Tank may be conveniently summarised by the formula—

$$\begin{aligned} E = & 2.476 + 1.477 \sin (n15^\circ + 241^\circ) \\ & + .621 \sin (n30^\circ + 35^\circ) \\ & + .256 \sin (n45^\circ + 170^\circ) \\ & + \dots\dots\dots (4) \end{aligned}$$

counting from midnight. In this formula the epoch of the first harmonic term agrees fairly well with the first terms in the formulae for temperature, wind, and vapour pressure<sup>2</sup> but no clue is given by the other terms enabling the various influential elements to be separated one from the other.

It appears from these results that no great advance in our knowledge of evaporation as a meteorological product is to be expected while the treatment is confined to the ordinary methods of statistical and analytical investigation; and that we should appeal rather to experiment. The rest of this paper, therefore, is a discussion of the Kenilworth observations largely from this point of view.

Tables 3 and 4 have been formed in the following way:—First certain of the meteorological elements (i.e., barometric pressures, air temperatures, quantities of evaporation from the Tank, and wind movements) have been tabulated according to season, for humidity percentages less than 40 per cent., and lying between 40 per cent. and 50 per cent. respectively. These again have been rearranged in sets, according to increase of velocity, each set being a sequence of barometric pressures. The quantities of evaporation and wind movement are for the whole day of 24 hours; the barometric pressures, air temperatures, and humidity percentages, are the means of 24 hourly readings. Days upon which any rain fell are not included. The yearly means and totals are the averages of the quarterly

<sup>1</sup> Hann, *Lehrbuch der Meteorologie*, p. 209. Hann remarks in passing that both daily and yearly periods of evaporation enclose themselves in the range of temperature more or less exactly, the daily period at any rate more than the yearly, upon which latter also the variation of the other meteorological elements has great influence.

<sup>2</sup> For these values see "An Elementary Synopsis, &c." *Transactions S.A. Phil. Soc.*, Vol. XIV., Part 2, p. 133.

numbers, on the assumption that the latter are normal means. The last column, "Evaporation corrected to 63 deg.," has been computed from the last but one by the addition of .008 inch to the observed evaporation for each decrease of temperature below 63 deg. This value is accepted from a previous paper.<sup>1</sup> In this connection the assumption is also made that the mean temperature of the air and of the water surface is the same. I have not been able to take hourly observations of the temperature of the water in the Tank nor to devise a trustworthy method of doing so by automatic means; but from occasional observations it seems a fair conclusion that for annual average results the temperatures of air and water may be called about equal, the latter being, perhaps, on the whole colder by day and warmer by night; its mean maximum being probably somewhat greater than that of the air in summer, but less in winter. The range of temperature in the Tank open to the sky should be greater than it is in the Tub screened from radiation. The mean temperature of the Tank is also probably somewhat the higher.

Only two facts stand out with any prominence from these Tables: that a decreased evaporation goes with a lower temperature, as well as with a gentler wind movement. The first is apparent in comparing the results season by season; the second in taking the average evaporation under each wind velocity. The quantities of evaporation (corrected for temperature to 63 deg.), arranged in order of wind velocity, are:—

Wind in Miles per Day.				Humidity below 40 per cent.	Humidity 40 per cent. -- 50 per cent.	Humidity below 50 per cent.
Less than	100	...	...	.143 in.	.168 in.	.155 in.
	100—150	...		.180	.167	.174
	150—200	..		.190	.186	.188
Greater than	200	...	...	.217	.203	.210

It appears from this last result also that a greater evaporation goes with a decreased humidity.

A further result is that by comparing winter and summer temperatures in Tables 3 and 4, we find a mean excess of evaporation per diem per degree of temperature of about .011 inch. We shall see presently that this value is perhaps made up of two parts.

With the object of removing some of the uncertainties of Tables 3 and 4, concomitant values of—

<sup>1</sup> "Results of some Experiments upon the Rate of Evaporation." *Transactions S.A. Phil. Soc.*, Vol. XIV., Part 1., p. 43.

- (1) the mean temperature of the air;
- (2) the mean temperature of the dew point;
- (3) the mean barometric pressure;
- (4) the total wind movement; and
- (5) the quantity of evaporation

have been tabulated for each day upon which the humidity ratio was between 40 per cent. and 45 per cent., rain days being rejected from the list as before. This particular range of mean daily humidity has been selected because it is found at all seasons, and is not as a rule accompanied by rain. The next step is to arrange the separate items in order of temperature. The result is given in Table 5.

According to this arrangement we observe that as the temperature rises—

- (1) the dew point rises;
- (2) the barometer falls;
- (3) the wind first increases and then decreases;
- (4) the evaporation increases.

In the Table the range of pressure is not great; and the wind velocity (which in any case will be less still on the ground) only varies between 5.2 and 6.7 miles per hour. Regarding, then, these two elements for the present as fixed, we may consider the evaporation, under the given conditions of humidity, as made up of three parts: one due to the temperature of the water, another to the temperature of the air, and the last to the amount of moisture in the air. As a first approximation we may express the relation by the formula—

$$E = K + aT + bt + cd \dots \dots \dots (5)$$

where E is the required quantity in inches of evaporation in one day,

K is the known mean evaporation,

T the deviation from the daily mean temperature of the air,

t the deviation from the daily mean temperature of the water.

d the deviation from the daily mean temperature of the dew point,

a, b, c, constants to be determined by trial.

The constant b may be put equal to .008 inch. By substituting in the formula from Table 5, supposing the mean temperatures of air and water to be the same, and solving the six resulting equations by the method of least squares, we find

$$E = .199 + .0034T + .008t + .0026d.$$

This equation is by no means exact. Five of the quantities of evaporation observed agree fairly well with those computed by the formula, but the first is considerably in error. The differences, too, seem to be progressive, the computed quantities increasing faster than those observed. An examination, however, of the individual numbers from which the observed means are deduced suggests that these differences would be less in a longer series. Moreover, there is still the outstanding uncertainty as to the mean temperature of the water—i.e., whether,

even if the annual means of air and water temperatures be the same, seasonal means and sequences will also be the same for each. The total temperature correction for air and water comes out at .0114 inch. This value is at any rate in very satisfactory agreement with the value .011 inch, deduced from Tables 3 and 4. The formula is, of course, only intended to express the deviation of evaporation at Kenilworth from the mean in a steady wind; it makes no pretence to be of general application.

The next step is to rearrange the corresponding elements in order of wind velocity. The average results are given in Table 6. The column entitled "corrected evaporation" has been computed from the constants of Table 5. It seems from this that, starting with a velocity of 3.4 miles per hour, the increase of evaporation varies as the square of the increase of velocity. This gives a greater evaporation than if the evaporation varied as the square of the velocity. Possibly, however, the latter is nearest the mark, although even itself too great.

Finally, the quantities of evaporation arranged in order of barometric pressure are given in Table 7. The last column gives the evaporation, corrected for temperature, dew point, and wind velocity, by the respective values previously found. Whatever the pressure correction may be, these results do not tell. Hann, in his *Handbook of Climatology*, states that "under similar conditions of relative humidity, temperature, and wind velocity, evaporation is much greater on mountains than at lower levels, because of the diminished pressure aloft. . . . The relative humidity alone is therefore no sufficient criterion for the evaporating powers of a mountain climate; the diminished pressure makes it possible for the water vapour which has been formed to be distributed much more rapidly through the air, and hence evaporation is accelerated."<sup>1</sup> Such a statement seems reasonable, *a priori*, although I have not met with any experiments which seem calculated to prove it for a water surface directly, as well as for a wet bulb thermometer. Certainly a range of pressure of one-third of an inch at Kenilworth is not sufficient to override the combined influence of other factors, not even when they have been to some extent allowed for.

The following passage, quoted from *Meteorological Apparatus and Methods*, is of interest in connection with the subject of this paper:—"Instead of measuring the temperature of the surface of evaporating water, as in the psychrometer, it is appropriate to measure the rate of the resulting evaporation, as in the evaporimeter. This measurement is usually considered as a means of ascertaining for engineering purposes the quantity of water lost by the earth or by reservoirs, etc., and as giving the meteorologists a crude approxima-

<sup>1</sup> Hann, *Handbook of Climatology* (Ward's Edition), p. 290.

tion to the quantity of water daily thrown into the atmosphere. But the rate and the temperature of evaporation are equally dependent on the dryness of the air and the velocity of the wind, and are therefore equally available as means of determining the hygrometric condition. Owing to the small mass involved in the temperature observations by the wet-bulb thermometer that instrument is adapted to give the momentary condition of the atmosphere. On the other hand, the large masses required in the measuring operations of the evaporimeter renders this instrument important to the meteorologists as a means of ascertaining the average hygrometric condition of the air during a long interval. From this point of view, therefore, this becomes an integrating hygrometer, and demands a more minute theoretical investigation than has as yet been given to it.

“At present we can only indicate the basis of this investigation. The most accurate observations available are those made in 1876 to 1882 by Desmond Fitz-Gerald, civil engineer, engineer in charge of the Chestnut Hill Reservoir, near Boston, Mass. Fitz-Gerald's observations combined with Stefan's work on diffusion should give a first approximate formula for the utilisation of the evaporimeter as an integrating hygrometer.

“Fitz-Gerald's measurements of the evaporation of water in pans 14.85 inches in diameter, in which one ounce of water is represented by a depth of 0.01 inch, gave him the value of  $E$ , or the depth of water in inches evaporated in one hour. These measures were made at the ordinary atmospheric pressures, and do not show any appreciable effect due to the ordinary range of the barometer at Boston. They are represented quite closely by an empirical formula similar to those deduced by other investigators, namely—

$$E = \{ 0.014 (V - v) + 0.0012 (V - v)^2 \} (1 + 0.67W^{.75}) \dots\dots\dots(6)$$

for which Fitz-Gerald uses the approximate expression

$$E = 0.0166 (V - v) (1 + W/2) \dots\dots\dots(7)$$

in which  $V$  is the vapour tension in inches of mercury corresponding to the temperature of the water:

$v$  is the vapour tension corresponding to the dew point in the free air;

$W$  is the velocity of the wind in miles per hour, measured by the Robinson Anemometer at the level of the water surface. Fitz-Gerald finds that the velocity recorded by an anemometer 30.5 feet above the water is three times that prevailing at the surface.

“Comparative observations made in the sunshine and the shade are equally well represented by the above formula. The evaporation from snow and ice was also measured with minuteness and found to be well represented by this formula.

“If, then, the temperature of the water is observed, so

that  $V$ ,  $E$ , and  $W$ , are known, then the Fitz-Gerald formula gives the average vapour tension in the free air during the time in which the evaporation was effected; for which purpose it may be written

$$v = V - 60E (1 + W/2) \dots \dots \dots (8)$$

This use of the evaporimeter, therefore, is additional to its ordinary use for engineering purposes, but implies that the temperature of the water and the velocity of the air at its surface be observed.<sup>1</sup>

It is interesting to compare Fitz-Gerald's formula with my results above. For daily totals, and a wind velocity at about 40 feet above the surface, the formula becomes

$$E = 0.4 (V - v) (1 + W/n) \dots \dots \dots (9)$$

where for Fitz-Gerald's gauges  $n = 6$ .

Substituting the wind velocities, and the vapour pressures suitable to the temperatures of Table 5, we find the denominator 6 considerably too small to satisfy the Kenilworth observations:  $n$  in fact ranging from 15 to 27, and averaging about 21. A large part of the reason, in point of magnitude, is undoubtedly due to the sheltered position of this station, but this does not account for the widely divergent values given in the column " $n$ " of Table 5. According to Fitz-Gerald's results, the evaporation in a calm will be doubled when the velocity at an altitude of 30 feet is 6 miles per hour; trebled when it is 12. For a temperature of 61.6 deg., and a dew point of 37 deg., the Fitz-Gerald formula gives an evaporation of .131 inch per diem, which is rather less than would be expected by Table 6; and a velocity of 18 miles per hour would give an evaporation of more than half an inch. Assuming the law of squares indicated by Table 6 to hold, however, the evaporation would be doubled when the velocity was 15 miles per hour, while a velocity of 21 miles per hour would give an evaporation of 0.5 inch.

Substituting the vapour pressures corresponding to the mean temperatures of Table 6 in Fitz-Gerald's formula, we have—

$$E = 0.205 = 0.4 (.618 - .246) (1 + 6.4/n) \dots \dots \dots (10)$$

giving  $n = 17$ .

If now we suppose the temperature of the water raised one degree, we shall find

$$E = 0.217 = 0.4 (.640 - .246) (1 + 6.4/17) \dots \dots \dots (11)$$

giving nearly the same increase as equation (5) gives when air and water together each rise through 1 deg. But if we take the denominator  $n = 6$ , the corresponding increase is  $E = .312$  to  $E = .330$  inch.

No doubt the difference between the value of  $n$  obtained by Fitz-Gerald, and that applicable to the Kenilworth results, may

<sup>1</sup> Cleveland Abbe, *Meteorological Apparatus and Methods*, p. 377.

be largely due to the great difference in the capacity of the evaporating vessels, and to the exposures of the same, so that it would be fruitless to venture to criticise the formula merely on the value of  $n$ . My difficulty is rather with the circumstance that the formula ignores the humidity of the air, indicating that under an assigned dew point a vessel of water at a given temperature will not lose any more in a warm (and dry) air than it will in a cold (and damp) air.

I have not seen Fitz-Gerald's paper, nor do I know upon what grounds the relative humidity is neglected either by its author or by the other investigators mentioned by Abbe. That its omission must be based on good reason, or what looks like good reason, is certain. At the same time its absence may not be altogether unquestionable, and it seems worth enquiry whether over and above the influence of the temperature of the water there should be a term or factor depending upon the temperature (or humidity, which comes to the same thing) of the air. It is possible that the temperature of the water is understood to depend upon the heat received from sun and air, and the heat lost in consequence of the degree of dryness of the air. If so it may apply better to mean conditions than to individual observations. That is, it may be more a summary than a law. Certainly it is not a law in the sense that the factor  $0.4 (V-v)$  marks the evaporation due to the temperature, and the factor  $(1-W/n)$  that due to the wind; for  $V$  itself largely depends upon  $W$ . On a dry, windy day the rapidity of evaporation will of itself considerably lower the temperature of the water surface. It is to the credit of the formula, as a summary, that applied to Table 5 the value of  $E/.4 (V-v)$  is not in any case greatly different from 1.3.

Of course, the best test would be furnished by a series of hourly temperatures of the water surface. These, unfortunately, do not exist at Kenilworth. But the matter may be investigated in another way; dealt with backwards, in fact. Suppose we take the mean values of Table 2, and from them compute the hourly water temperatures. Then

$$V = nE/6 (n+W) + v \dots\dots\dots (12)$$

The exact value of  $n$  is immaterial, and will not affect the temperature sequences. In the present case it is computed equal to 16 from the mean values of Table 2.

From this formula we determine the computed water temperatures of Table 2. It remains to compare them with observation.

Some summer observations of the temperature of the water during 1904 at selected hours gave the following differences of temperature, air *minus* water:

VIII.	IX.	XIII.	XVII.	XX.	XXIII.
-4.1	-1.1	-3.1	-4.1	-7.1	-8.5

These differences would, no doubt, be somewhat modified in a longer series of observations, but they show at any rate that at



a season when evaporation is on the whole fairly rapid, the temperature of the air falls after sunset much more rapidly than that of the water. Now the summer rates of fall of temperature must be more important than the winter rates, because the summer evaporation is greater, and therefore the latter must impress its character upon the evaporation for the year. So that if we assume that the summer rates hold all through the year, we shall err, if at all, on the right side. As we have simply to compare the shapes of the curves of computed and observed water temperatures, we will suppose them to agree at XIII. Then they are

	VIII.	IX.	XIII.	XVII.	XX.	XXIII.
Computed ...	60°.6	62°.3	72°.7	67°.9	60°.0	57°.6
Observed ...	56°.5	59°.0	72°.7	69°.9	62°.6	59°.0

This gives the result that the computed temperatures, based as we know upon the observed evaporation, are greater before noon, and less after, than the observed temperatures. That is, while the relative humidity is falling the evaporation is greater than it should be for a given water temperature, and while the humidity is rising the evaporation is less; and, moreover, the differences between the observed and computed temperatures are actually nearly at their greatest when the change of humidity is most rapid. This seems to suggest, if not to prove, that the temperature (or humidity) of the air has some influence upon the rate of evaporation, but it proves nothing as to the mode of action. We should expect, to begin with, that any postulated increment of evaporation due to an increase of humidity, over and above that due to the temperature of the water, would be greater or less than the mean according as the humidity was less or greater. This, on the face of it, is not so; and it follows, therefore, that the process must be indirect, or, perhaps it would be better to say, sluggish.

The following experiment was arranged with the idea of examining this result, and incidentally illustrating the process of evaporation from a water surface and the diffusion of the derived vapour in a quiet air. A copper evaporation gauge, five inches diameter and five inches deep, was placed about two feet above the ground under a large louvred screen, and kept as nearly as possible half full of water. A psychrometer with its two spherical bulbs three inches apart was so mounted that the bulbs were very nearly three-quarters of an inch above the water surface, and therefore a little less than two inches below the rim of the gauge. The wet bulb was supplied with moisture by means of a thin wick attached beneath, instead of round the neck; and dipping into the water of the gauge. About 18 inches above this psychrometer, and in free air, was another of ordinary pattern, in every way similar to the first except that the bulbs were five inches apart, the wick attached to the neck of the wet bulb in the ordinary way, and supplied with water from a glass cup. Simultaneous observations of the



readings of the two psychrometers and of the temperature of the water surface in the gauge were made from time to time.

The wet and dry bulb observations were reduced for dew point and relative humidity by means of Glaisher's Tables, these being possibly better for the purpose than the Smithsonian Tables, which premise a forced draught. Naturally the error of the dew point, by whatever Tables deduced, must be appreciable; although, since the environment of the psychrometer within the gauge is somewhat humid, and the water surface not differing greatly from the air in temperature, the wet bulb should read at least as near the truth as a wet bulb in the still air of a room, for example. With regard to the choice of Hygrometer Tables, it happens that a forced draught makes very little difference to a wet bulb properly screened when the relative humidity is high. In any case since the main argument is based on sequences of numbers rather than upon absolute values, the method of reduction is not of the greatest consequence.

The humidity ratios observed (and so computed) ranged between 22 per cent. and 97 per cent. in the air, and between 32 per cent. and 100 per cent. inside the gauge. The water temperatures ranged between 59 deg. and 84 deg.; the air temperatures between 60 deg. and 90 deg. The wet bulb inside the gauge was always higher than that outside. The dry bulb inside the gauge stood nearly always between the temperature of the water and that of the outside air. It stood sometimes, I fancy, lower than it should; for when the water was cooler than the air, an independent thermometer introduced beside the same dry bulb read at times as much as 0.5 deg. higher, and would remain higher for some time. I have not discovered the reason of this. The cooling may be due to a deposit of a very thin film of moisture upon the bulb; but if so the deposit was not visible under a strong magnifying glass.

The wind seems to have had no demonstrable influence upon the relative readings of the psychrometers. At any rate, whatever its influence may have been, it was lost in the crowd of others. The following are the differences of the computed dewpoints for assigned winds:—

Wind, in Miles Per Hour.	Difference of Dew Points.
0—2	4.6 deg.
2—4	4.0 deg.
4—6	4.0 deg.
6—8	3.7 deg.
8—10	4.3 deg.
Greater than 10	4.5 deg.

In Table 8 will be found the mean results, arranged in order of humidity. The fourth column gives the differences of computed humidity between the inside and outside of the gauge for average intervals of about 10 per cent. Evidently

when the outside air is saturated such difference must be zero. As the air gets drier, the difference increases step by step until a humidity of about 60 per cent. in the free air is reached. After this the tendency seems to be for a stationary difference of 10 per cent. more or less, or even, if the method of determining the humidity can be trusted to such a degree of accuracy, to a decrease. At any rate, the drying power of the outside air, when it is less than half saturated, upon the inside wet bulb, is greater than the moistening power of the stratum of water beneath. Throughout the experiment there was not much difference between the temperatures of the water in the gauge and of the free air. When the humidity of the air was between 20 per cent. and 30 per cent. the average temperature of the water was about 85 deg., that of the air about 87 deg. When the humidity of the air was between 90 per cent. and 100 per cent. the temperature of the water was about 63 deg., that of the air about 62 deg. Upon any theory much more water must have been evaporating at the higher temperature, and therefore if there were no diffusion outside the gauge the vapour tension immediately above the water would be higher at the lower humidity than it would be at the higher. But since the tension is actually lower (see Table 8), it follows that the rate of diffusion in the free air is greater as the temperature of the air rises. This result, therefore, is not antagonistic to our previous result that an increasing air temperature<sup>1</sup> will quicken the evaporation from a water surface of given temperature.

A variation of this part of the subject is introduced in Table 9. The water temperatures are arranged in sets, 60 deg.—65 deg., 65 deg.—70 deg., etc., and compared with the other corresponding elements; each set being then subdivided into sections of high, mean, and low humidity. A number of interesting results may be obtained from this Table. We see first of all that while the water temperature is rising, and the vapour tension at its surface consequently increasing, the dew point in the free air, as it happens, is falling. Now when this fall of the dew point is relatively rapid we see that the vapour tension inside the gauge falls, whereas when the fall is slow the vapour tension inside the gauge increases. For instance, consider the rise of water temperature from 62.6 deg to 66.8 deg.: the decrease of vapour tension in the free air in this case is .011 inch, i.e., from .439 inch to .428 inch, whereas the vapour tension inside the gauge rises from .475 inch to .480 inch. Again, consider the rise of water temperature from 62.2 deg. to 78.2 deg. The concomitant vapour tension in the free air here falls .043 inch, i.e., from .399 inch to .356 inch, while the vapour tension within the gauge remains nearly constant. Or, taking averages, the vapour tension inside the gauge will increase, remain constant, or decrease, according as the fall of

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<sup>1</sup> Or a decreasing humidity.

vapour tension in the free air is less than, equal to, or greater than, .033 inch per rise of 10 deg. of water temperature. It seems to be a fair inference that a high temperature, or in other words a low humidity, of the free air does tend to promote the decrease of vapour tension in the stratum of air lying upon water, and so must quicken the rate of evaporation.

These issues are set forth here more as a basis for future research when the opportunity shall at last come, than as demonstrated facts. Granting their truth, then a more or less humid air behaves to the emanations of material particles from a water surface much as it does to the radiation of dark heat from cooling terrestrial substances. If I understand Professor Very aright, the aqueous vapour of the atmosphere, whatever its state, will check the radiation of heat from the earth;<sup>1</sup> it is known besides that the more humid the air the less the radiation; that is to say, the total effect consists of two parts, one due to the aqueous vapour as such, the other to its condition in relation to the prevailing temperature. In the same way evaporation would seem to be checked both by the quantity of aqueous vapour present in the atmosphere, and by its humid condition. Maxwell has remarked that "the rate at which the diffusion of any substance goes on is in every case proportional to the rate of variation of the strength of that substance in the fluid as we pass along the line in which the diffusion takes place. Each substance in a mixture flows from places where it exists in greater quantity to places where it is less abundant. The law of diffusion of matter is therefore of exactly the same form as that of the diffusion of heat by conduction."<sup>2</sup> It would be interesting to examine the above results in the same connection. For while Maxwell's remarks apply more particularly to quantity, these deal also with quality. Stefan's diffusion formula, as quoted by Preston (I have not seen the original), is also based on the quantity of vapour, and takes no account of the humidity: "If  $a$  be the radius of a circular basin,  $k$  the coefficient of diffusion,  $P$  the atmospheric pressure,  $p'$  and  $p''$  the pressure of the vapour at the surface and very far away from it respectively, the mass of vapour which escapes from the basin per unit time is

$$M = 4ka (P - p'')/(P - p') \dots \dots \dots (13)$$

Thus  $M$  is proportional to the radius of the basin and not to its surface, as commonly supposed."<sup>3</sup> Evidently, if my experiments described above are to be trusted,  $k$  would have to change a little with every change of relative humidity.

<sup>1</sup> F. Very, *Atmospheric Radiation*, *passim*.

Maxwell, *Theory of Heat*, p. 276. See also by the same author, Art. "Diffusion," *Enc. Brit.*, 9th Ed., Vol. VII., p. 215.

<sup>3</sup> Preston, *Theory of Heat*, p. 291.

TABLE 1.—COMPARATIVE TABLE OF MEAN ANNUAL EVAPORATION.

		PICHE ATMOMETER.				SCREENED TUB.				TANK.	
		Night.	Day.	Monthly Totals.	Greatest in One Day.	Night.	Day.	Monthly Totals.	Greatest in One Day.	Monthly Totals. XXIV—XXIV	Greatest in One Day.
		XX VIII—XX VIII	XX VIII—XX VIII	XX—XX	One Day.	XX VIII—XX VIII	XX VIII—XX VIII	XX—XX	One Day.		
		Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
January	...	2.89	6.82	9.71	.55	3.11	5.42	8.53	.53	8.626	.483
February	...	2.03	5.26	7.29	.46	2.20	3.76	5.96	.40	5.947	.383
March	...	1.61	4.32	5.93	.43	1.54	3.19	4.73	.33	4.935	.368
April	...	1.13	3.21	4.34	.33	.98	.2.18	3.16	.26	3.162	.175
May	..	1.40	3.81	5.21	.26	1.09	2.46	3.55	.30	2.583	.149
June	...	1.11	2.96	4.07	.24	.72	1.90	2.62	.18	1.666	.103
July	...	1.12	3.51	4.63	.33	.84	2.10	2.94	.23	1.853	.125
August	...	1.77	4.72	6.49	.33	1.38	2.91	4.29	.33	3.112	.191
September	...	2.02	5.73	7.75	.55	1.72	3.64	5.36	.42	4.324	.257
October	...	2.65	6.53	9.18	.55	2.39	4.64	7.03	.42	6.326	.345
November	...	3.01	7.48	10.49	.57	3.27	5.79	9.06	.59	8.393	.414
December	..	2.67	6.58	9.25	.48	2.84	5.23	8.07	.48	8.505	.462
Year	...	23.41	60.93	84.34	.57	22.08	43.22	65.30	.59	59.432	.483

TABLE 2.—COMPARATIVE TABLE OF METEOROLOGICAL ELEMENTS.

	Dry Bulb Temp.	Wet Bulb Temp.	Dew Point Temp.	Humidity	Wind Velocity	Evaporation (Tank)	Dry Bulb Rise from Minimum	Wet Bulb Rise from Minimum	Dew Point Rise from Minimum	Humidity Fall from Maximum	Wind Velocity Rise from Minimum	Evaporation from Rise from Minimum	Computed Temp. of Water.	Air above Water
	°	°	°		in. per hr.	in.	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.	°	°
Midnight	58.3	48.7	41.7	60.9	4.5	1.480	193	214	167	272	138	24	56.6	0.3
I.	53.1	48.2	41.5	63.1	4.3	1.474	147	170	167	216	105	21	56.5	-1.4
II.	54.0	47.7	41.6	63.3	4.2	1.430	104	125	139	139	79	9	56.3	2.3
III.	53.0	47.2	41.5	67.0	4.1	1.417	86	80	111	116	53	6	56.1	3.1
IV.	52.2	46.7	41.2	68.4	4.0	1.401	35	36	28	80	26	"	55.9	-3.7
V.	51.3	46.7	41.1	70.0	3.9	1.485	"	"	"	38	"	"	56.1	4.8
VI.	51.1	46.6	41.7	71.2	3.9	1.550	93	27	167	"	"	24	57.8	6.5
VII.	53.7	48.0	42.6	68.5	4.3	1.802	93	152	417	77	105	106	59.4	5.7
VIII.	59.3	50.9	43.7	59.1	5.1	1.802	300	411	723	319	316	144	60.6	-1.3
IX.	64.8	53.5	44.5	50.1	6.8	2.051	521	643	945	550	353	191	62.3	+2.5
X.	69.1	55.2	44.7	44.0	7.3	2.447	587	785	1000	707	763	309	64.8	+4.3
XI.	72.4	56.4	44.6	38.4	7.5	3.007	915	102	973	825	947	473	67.6	+4.8
Noon	74.9	57.0	44.3	36.0	7.7	3.088	911	955	890	912	1000	879	70.6	+4.3
XIII.	76.5	57.2	43.8	35.7	7.7	4.387	973	973	751	971	1000	974	72.7	+3.8
XIV.	77.2	57.4	43.6	32.7	7.6	4.783	1000	1000	695	997	1000	1000	73.6	+3.6
XV.	77.2	57.2	43.3	32.6	7.3	4.808	1000	1000	612	1000	973	879	73.0	+4.2
XVI.	76.1	56.7	43.1	33.6	7.3	4.388	937	920	536	985	894	879	70.6	+3.5
XVII.	72.7	56.0	43.8	39.0	6.6	3.710	826	866	151	835	710	679	67.9	+4.8
XVIII.	68.2	54.2	43.5	44.7	5.0	2.854	632	705	607	689	447	428	64.3	+3.9
XIX.	64.6	52.7	43.3	49.2	4.8	2.245	513	571	612	573	237	250	61.6	+3.0
XX.	62.4	51.7	42.9	51.9	4.9	1.935	428	482	500	504	293	156	60.0	+2.4
XXI.	60.5	50.7	42.3	54.1	4.8	1.819	355	393	334	462	237	124	58.9	+1.6
XXII.	58.9	50.0	42.1	56.5	4.7	1.731	293	330	278	386	290	94	58.4	+0.5
XXIII.	57.4	49.3	41.8	58.6	4.6	1.717	235	288	185	331	184	44	57.6	0.2
Midnight	56.3	48.7	41.7	60.9	4.6	1.529	163	214	167	272	138	24	56.6	0.3
Year	63.3	51.0	42.8	52.1	5.6	59.452	463	500	473	499	447			

\* By Fitzgerald's Formula.

TABLE 3.—QUANTITIES OF EVAPORATION FOR HUMIDITY PERCENTAGES LESS THAN 40%  
WIND VELOCITY less than 100 miles per day.

JANUARY TO MARCH.				APRIL TO JUNE.				JULY TO SEPTEMBER.				OCTOBER TO DECEMBER.				YEAR (Average of Seasons).			
No.	Pressure.		Temperature.	Evaporation.	No.	Pressure.		Temperature.	Evaporation.	No.	Pressure.		Temperature.	Evaporation.	No.	Pressure.		Temperature.	Evaporation corrected to 63°.
	Inches.	Inches.	Inch.			Inches.	Inches.	Inches.			Inch.	Inches.	Inches.			Inch.	Inches.	Inches.	
2	25.972	25.972	73°	.240	...	...	...	...	.151	...	25.996	76°	.302	...	3	25.996	26.072	67°	.175
7	26.050	26.050	74	.268	5	26.081	26.081	61°	.161	5	26.075	71	.257	.207	9	26.075	26.140	72	.142
2	26.106	26.106	81	.247	5	26.161	26.161	66	.145	5	26.134	73	.286	.214	5	26.134	26.244	70	.111
...	...	...	...	...	5	26.236	26.236	63	.080	1	26.252	76	.190	.167	1	26.252	...	...	...
...	...	...	...	...	3	26.346	26.346	60	...	...	...	...	...	...	...	...	...	...	...

WIND VELOCITY from 100 to 150 miles per day.

7	25.979	25.979	77	.338	.338	...	...	...	...	...	...	12	25.974	25.974	74	.303	.303	.230
18	26.048	26.048	78	.289	.289	...	...	...	...	...	...	36	26.033	26.033	76	.294	.294	.169
10	26.120	26.120	75	.271	.271	...	...	...	...	...	...	10	26.140	26.140	70	.252	.252	.167
...	...	...	...	...	...	6	26.254	26.254	57	.138	.138	5	26.240	26.240	74	.197	.197	.152
...	...	...	...	...	...	1	26.307	26.307	60	.086	.086	...	...	...	...	...	...	...

WIND VELOCITY from 150 to 200 miles per day.

2	25.883	25.883	75	.390	.390	...	...	...	...	...	...	...	...	...	...	...	...	...
7	25.969	25.969	76	.307	.307	...	...	...	...	...	...	16	25.971	25.971	74	.343	.343	.221
13	26.039	26.039	77	.310	.310	...	...	...	...	...	...	20	26.028	26.028	74	.324	.324	.183
1	26.152	26.152	82	.313	.313	...	...	...	...	...	...	5	26.127	26.127	62	.273	.273	.181
...	...	...	...	...	...	...	...	...	...	...	...	3	26.234	26.234	61	.206	.206	.173

WIND VELOCITY greater than 200 miles per day.

4	25.851	25.851	72	.406	.406	...	...	...	...	...	...	2	25.875	25.875	72	.340	.340	...
8	25.939	25.939	77	.419	.419	...	...	...	...	...	...	14	25.950	25.950	74	.360	.360	.236
5	26.027	26.027	73	.315	.315	...	...	...	...	...	...	13	26.045	26.045	71	.291	.291	.191
...	...	...	...	...	...	...	...	...	...	...	...	2	26.147	26.147	71	.267	.267	.223

TABLE 4.—QUANTITIES OF EVAPORATION FOR HUMIDITY PERCENTAGES LYING BETWEEN 40% AND 50%.  
WIND VELOCITY less than 100 Miles per day.

JANUARY TO MARCH.			APRIL TO JUNE.			JULY TO SEPTEMBER.			OCTOBER TO DECEMBER.			YEAR (Average of Seasons).		
No.	Pressure.	Temperature.	Evaporation.	No.	Pressure.	Temperature.	Evaporation.	No.	Pressure.	Temperature.	Evaporation.	Pressure.	Temperature.	Evaporation corrected to 68° F.
...	Inches.	Inch.	Inch.	...	Inches.	Inch.	Inch.	...	Inches.	68°	Inch.	Inches.	Inch.	Inch.
11	26.058	73	.217	5	26.055	62	.124	...	5	26.058	70	26.057	67	.146
6	26.143	72	.187	7	26.146	58	.084	...	8	26.140	64	26.148	62	.141
...	...	...	...	16	26.245	57	.082	...	1	26.221	58	26.234	57	.176
...	...	...	...	8	26.320	54	.086	...	1	26.303	62	26.317	57	.171
...	...	...	...	2	26.436	47	.060	...	...	...	...	...	...	...

WIND VELOCITY from 100 to 150 Miles per day.

5	25.975	75	.277	...	...	...	...	...	4	25.970	70	...	...	...
10	26.056	74	.239	3	26.054	61	.102	...	8	26.043	67	26.055	65	.172
8	26.126	72	.218	4	26.126	55	.074	...	8	26.143	67	26.140	63	.161
...	...	...	...	2	26.282	52	.066	...	4	26.230	73	26.246	64	.136
...	...	...	...	2	26.340	52	.096	...	1	26.308	70	26.321	62	.146
...	...	...	...	...	...	...	...	...	1	26.407	57	26.418	52	.220

WIND VELOCITY from 150 to 200 Miles per day.

2	25.892	77	.340	...	...	...	...	...	...	...	...	...	...	...
6	25.966	75	.315	...	...	...	...	...	8	25.955	73	25.946	64	.222
6	26.057	76	.250	6	26.059	57	.092	...	9	26.052	71	26.052	63	.193
2	26.111	68	.253	2	26.117	54	.093	...	7	25.144	70	26.134	63	.181
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	1	26.301	54	.104	...	2	26.380	69	26.353	63	.147

WIND VELOCITY greater than 200 Miles per day.

...	...	...	...	...	...	...	...	...	1	25.757	57	...	...	...
...	...	...	...	...	...	...	...	...	1	25.857	75	...	...	...
2	25.947	80	.360	2	25.963	60	.149	...	5	25.956	69	25.959	67	.204
5	26.038	70	.280	1	26.053	60	.147	...	6	26.062	67	26.055	63	.202
1	26.179	73	.266	...	...	...	...	...	5	26.138	63	26.133	64	.180
...	...	...	...	...	...	...	...	...	1	26.281	54	26.278	58	.227
...	...	...	...	...	...	...	...	...	1	26.359	53	...	...	...

TABLE 5.—QUANTITIES OF EVAPORATION ARRANGED ACCORDING TO TEMPERATURE.

(Humidity 40% to 45%.)

No. of Observations.	Temperature.	Dew Point.	Pressure.	Wind Velocity.	Evaporation per day.	Evaporation corrected to 65.4°	n
			Inches.	Miles per day.	Inch.	Inch.	
30	52.6	30	26.208	141	.120	.222	20
32	57.9	34	.185	130	.137	.197	27
24	62.9	38	.121	125	.185	.205	15
19	67.9	42	.129	139	.213	.193	20
26	73.1	47	.063	148	.258	.196	20
30	77.8	52	.025	162	.283	.184	26
161	65.4	40.5	26.122	141	.199	.199	18

TABLE 6.—QUANTITIES OF EVAPORATION ARRANGED ACCORDING TO WIND VELOCITY.

(Humidity 40% to 45%.)

No. of Observations.	Wind Velocity.	Temperature.	Dew Point.	Pressure.	Evaporation per day.	Corrected Evaporation.
	Miles per day.			Inches.	Inch.	Inch.
41	82	61.6	37	26.176	.153	.184
55	128	65.1	40	.137	.188	.188
46	172	67.6	42	.085	.225	.203
19	229	66.0	41	.066	.252	.245
161	153	65.1	40	26.116	.205	.205

TABLE 7.—QUANTITIES OF EVAPORATION ARRANGED ACCORDING TO PRESSURE.

(Humidity 40% to 45%.)

No. of Observations.	Pressure.	Temperature.	Dew Point.	Wind Velocity.	Evaporation per day.	Corrected Evaporation.
	Inches.			Miles per day.	Inch.	Inch.
23	25.965	73	46	182	.303	.222
52	26.056	69	44	147	.225	.205
44	.138	63	38	136	.171	.203
42	.284	58	34	118	.131	.210
161	26.111	66	40.5	146	.207	.207



TABLE 8.—COMPARISON OF MOISTURE CONDITIONS WITHIN AND WITHOUT THE EVAPORATION GAUGE, ARRANGED IN A SEQUENCE OF RELATIVE HUMIDITY.

Humidity of the Free Air. H"	Mean Humidity inside Gauge. H	Mean Humidity outside Gauge. H"	Difference. H"—H"	Mean Dew Point inside Gauge. D	Mean Dew Point outside Gauge. D"	Difference. D"—D"	Mean Vapour Tension inside Gauge. V"	Mean Vapour Tension outside Gauge. V"	Difference. V"—V"	Wind Velocity. mils. per hour	Number of Observ- ations.
							Inch.	Inch.	Inch.		
20—30	35.4	26.0	9.4	53.8	47.1	6.7	.414	.323	.091	5.1	11
30—40	44.6	34.3	10.3	54.8	48.7	6.1	.429	.343	.086	5.9	27
40—50	54.5	43.8	10.7	56.3	51.3	5.0	.453	.377	.076	4.4	34
50—60	64.4	54.2	10.2	56.2	52.6	3.6	.451	.396	.055	4.9	21
60—70	73.3	64.4	8.9	58.8	55.6	3.2	.495	.441	.054	6.1	24
70—80	81.7	74.8	6.9	60.1	57.5	2.6	.519	.473	.046	3.4	12
80—90	87.4	83.6	3.8	61.3	59.3	2.0	.541	.504	.037	5.1	17
90—100	95.6	92.3	3.3	61.7	60.0	1.7	.549	.517	.032	4.3	10

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TABLE 9.—COMPARISON OF VAPOUR TENSIONS WITHIN AND WITHOUT THE EVAPORATION GAUGE, ARRANGED IN A SEQUENCE OF WATER TEMPERATURES.

Mean Water Temperature.	Humidity of the Free Air.	Mean Vapour Tension at the Water Temperature.	Mean Vapour Tension inside Gauge.	Mean Vapour Tension outside Gauge.	Difference.	Difference.	Difference.
	H''	W	V'	V''	W—V'	V'—V''	W—V''
	<div><div>c</div><div>°</div></div>	Inch.	Inch.	Inch.	Inch.	Inch.	
79·3	28·1	·999	·414	·324	·585	·090	·675
78·2	32·8	·963	·445	·356	·518	·089	·607
77·2	37·0	·932	·473	·386	·459	·087	·546
72·6	38·6	·799	·431	·349	·368	·082	·450
72·6	44·4	·799	·463	·385	·336	·078	·414
72·7	51·7	·802	·508	·432	·294	·076	·370
67·1	49·3	·663	·434	·373	·229	·061	·290
66·8	62·2	·656	·480	·428	·176	·052	·228
66·6	74·9	·651	·524	·480	·127	·044	·171
62·2	64·6	·559	·442	·399	·117	·043	·160
62·6	74·3	·567	·475	·439	·092	·036	·128
63·1	87·5	·577	·526	·495	·051	·031	·082



## **SECTION B.**

**ANTHROPOLOGY AND ETHNOLOGY, BACTERIOLOGY, BOTANY,  
GEOGRAPHY, GEOLOGY AND MINERALOGY, ZOOLOGY.**



## SECTION B.

### PRESIDENT'S ADDRESS.

## THE HISTORY OF STRATIGRAPHICAL INVESTIGATION IN SOUTH AFRICA.

BY GEO. S. CORSTORPHINE.

At a meeting such as this we may well take the opportunity of recording our scientific progress, and reviewing some of the problems which still await solution. As, however, it would be impossible for anyone to deal adequately with even half of the departments of science included in Section B, it seems most appropriate that I should confine myself to the subject to which my own energies are devoted, and place before you some portion of our geological knowledge which may perhaps prove of general interest. I shall, therefore, with your permission, sketch the history of stratigraphical investigation in South Africa, and try to show to what extent we have arrived at a solution of the questions involved, and how much yet remains to be done.

Geological inquiry, like all scientific work over so extended an area as South Africa, is bound for a long time to result simply in a series of unconnected observations, and we find that much of the earlier geological literature, and even some of the later, is not a little puzzling by its indiscriminate nomenclature and absence of connected view. At the present day we are fortunate in having not only a considerable number of able private workers, but also systematic geological surveys carried on by the governments of the Cape, the Transvaal, and Natal, by means of which all the work will in time be co-ordinated, and so gradually give us accuracy in details, as well as a more scientific grasp of the broad problem of the evolution of this portion of the earth's surface.

In dealing with the present subject I have found it preferable not to follow a strictly logical order, but to make such divisions as best coincide with the historical development of our knowledge. The first portion of this address, therefore, refers to the ground-work of South African stratigraphy as laid down by A. G. Bain; this is followed by a history of the controversy regarding the Pre-Karoo rocks of southern Cape Colony; then in order, the old rocks of the north, the much-discussed glacial conglomerate and the rocks of the Karroo, the Natal sequence, the Cretaceous rocks of South Africa, and the

stratigraphy of the Transvaal are considered. A discussion of the correlation of the formations occurring in the different parts of South Africa forms the final section.

#### THE GROUND-WORK OF SOUTH AFRICAN STRATIGRAPHY.

The first field for geological investigation in South Africa was naturally offered by the Cape Colony, and real South African geology begins with the work of Andrew Geddes Bain. It is true that visitors and travellers such as Barrow,<sup>1</sup> Lichtenstein,<sup>2</sup> Clarke Abel,<sup>3</sup> and Itier,<sup>4</sup> recorded many interesting geological facts, and even, in the case of the two last named, gave detailed accounts of individual localities. None of this work, however, can be compared with that of Bain, of whose researches I do not think it is possible to speak too highly.

“He made,” as he himself wrote, “the first attempt “to give the varied formations of this (the Cape) Colony a “local habitation and a name, without the shadow of a “foundation to commence upon but what his own observa- “tion suggested. He had no predecessors whose labour he “could avail himself of, nor contemporaries whose assist- “ance he could solicit, but for fourteen years was groping “about in the dark, as it were, through virgin fields hitherto “quite untrodden, and as far as geology goes a perfect “*terra incognita*.”<sup>5</sup>

His first incitement to geological work, he tells us, came from reading Lyell's Principles of Geology, which he had borrowed from a friend.<sup>6</sup> He was forty years of age when he began, and, before he finished, he gave a correct outline of the geological succession and structure of the Cape Colony.

Bain placed his work before the Geological Society of London in two papers,<sup>7</sup> and with the second of these he gave the first geological map of South Africa, and a series of sections, illustrating his views of the succession of the strata and their structural relationships. He made a very large collection of fossil remains from the east and west of Cape Colony, and among these the first of the peculiar Karroo reptiles were sent home to be described by Professor Owen.<sup>8</sup> Invertebrate remains from the Bokkeveld Beds were also in the collection, and these afforded the material for the first detailed description of the fossils from these rocks.<sup>9</sup> About the same time, with his friend Dr. Atherstone, to whom he had imparted some of his own enthusiasm, Bain made a collection of the secondary fauna of the rocks near Uitenhage, the description of which by

<sup>1</sup> Barrow, 7.\*    <sup>2</sup> Lichtenstein, 58.    <sup>3</sup> Clarke Abel, 1.    <sup>4</sup> Itier, 49.

<sup>5</sup> From the original MS. of the introduction to his paper “On the Geology of Southern Africa.”

<sup>6</sup> Reminiscences and Anecdotes connected with the History of Geology in South Africa. East. Prov. Mon. Mag., 1856. Reprinted in Trans. Geol. Soc. S. Afr., Vol. II., pp. 59—75, 1896.

<sup>7</sup> Bain, 5, 6.    <sup>8</sup> Owen, 65.    <sup>9</sup> Sharpe and Salter, 94, Sharpe, 92.

\* These numbers refer throughout to the literature list given at the end of this paper.

Daniel Sharpe is the most detailed account of these fossils so far published.<sup>1</sup>

I give, on the chart appended to this address, Bain's succession of the strata of the Cape Colony, and, if we compare his view of the sequence with those held by later writers, we cannot but admire the insight shown by this early worker. Bain deserves to rank among the geological geniuses, and it is pleasant to know that his merit received due recognition, and even financial reward, at the hands of the Geological Society of London, the British Museum, and the Home Government.

Practically the only error into which Bain fell was in connection with a rock which puzzled many of his successors. His "claystone porphyry"—an old name for what would now be known as a quartz-porphry—is the much discussed and interesting Ecça or Dwyka Conglomerate, which he held to be

"the production of an immense volcano, which we may  
 "suppose to have existed somewhere near the junction  
 "of the Vaal and Orange Rivers, or perhaps about the site  
 "of the present Compass Berg, whose peak rises to the  
 "height of 10,000 feet above the sea-level; and thence  
 "deluged with fiery billows the Silurian (?) plains, and  
 "spread ruin and desolation over the carboniferous forests  
 "for tens of thousands of square miles." <sup>2</sup>

While offering this explanation, however, he admits that he is in a dilemma, because he saw some indications that the rock had been produced by water action, but, as he could find no trace of stratification, he felt unable to confirm this view.

That Bain did not recognise the true origin of the ancient South African glacial deposit need not detract from his fame, for many men with greater educational advantages, and with knowledge of recent icework as a standard for comparison, have spoken with hesitation, doubt, and even denial of the glacial origin of this conglomerate.

Like William Smith, "the father of English geology," Bain was a road-maker, and, though generously treated by the home government, he never seems to have received any recognition of his geological work from his immediate employer, the Cape Government. That body was not, however, unaware of the advantages of geology to the state, and, while Bain was still alive, it engaged from England a Mr. Andrew Wyley as government geologist. Wyley's time was "occupied with purely mineral questions for two and a half years," and he had "the short space of eighteen months for the whole problem of Cape geology," so, as he said, those who are acquainted with the history of geology will scarcely feel surprised that he was not able to solve it.<sup>3</sup> His published work, in what we may term pure geology, consists of a short report with a longer appendix issued somewhat later,<sup>4</sup> He also

<sup>1</sup> Sharpe, 91.

<sup>2</sup> Bain, 6, p. 186.

<sup>3</sup> Wyley, 106, p. 5.

<sup>4</sup> Wyley, 107.



made a map and sections, which were lodged in manuscript in the Colonial Office, but which were vainly looked for several times, at my request, while I was in Cape Town.

In the appendix to his report Wyley gave a tabular view of the succession of Cape strata, and there it will be seen that he was very definite in his correlation of South African with European strata—more so than his knowledge justified, more definite even than we can be to-day. Wyley's contribution to South African geology was not an important one—he made no addition to Bain's exposition of the general structure of the country, and his diffuse, rambling observations are buried among a mass of varied information arranged in the diary form of a field note-book. Coming after Bain—to whose work he makes curt reference—Wyley does not impress one, and the first official geologist in South Africa is now known chiefly by the title of the appendix to his report, and as the introducer of the term “trap conglomerate,” in place of Bain's claystone porphyry, for the rock known later as *Ecce conglomerate* or *Dwyka conglomerate*. He practically adopted the succession given by Bain, but added thereto his hasty and unwarranted correlation with European strata, which led to much misconception, especially among writers elsewhere who referred to his work.

#### THE CONTROVERSY OVER THE PRE-KARROO SEQUENCE.

Almost contemporaneously with Wyley, Dr. R. N. Rubidge, of Graaff-Reinet, and later of Port Elizabeth, wrote several papers on South African geology.<sup>1</sup> His observations led him to take a different view of the succession and relationship of the four oldest divisions of the rocks in south-western Africa than that which Bain set forth. Rubidge was of opinion that the Malmesbury slates beneath, and the Bokkeveld shales above, the Table Mountain Sandstone, were the same, and that the Witteberg quartzites above the Bokkeveld Beds were on the same horizon as the Table Mountain Series. Had this reading been correct it would have had the merit of simplicity. Unfortunately the idea was based on erroneous observations taken on “two hasty journeys.”<sup>2</sup> By a curious chance, however, Rubidge gained support from a distinguished traveller, von Hochstetter, who visited South Africa with the Austrian “Novara” Expedition (1857-59), and made a trip to the country near the Zonder Einde Mountains.<sup>3</sup> Owing, perhaps, to the faulted junctions there exposed, Hochstetter thought the fossiliferous Bokkeveld Beds probably underlay the Table Mountain Sandstone, but he states that he could not have come to this conclusion had he not had the support of Rubidge's reading of the Ceres section. Thus an error arose which long held sway, and found supporters even as late as 1897.

That this perverted view of the succession of the oldest

<sup>1</sup> Rubidge, 76, 77, 77a.

<sup>2</sup> Rubidge, 77, p. 196.

<sup>3</sup> Hochstetter, 46.

formations should have existed so long, is the more peculiar from the fact that it was not supported by the work of Mr. E. J. Dunn, who, on his first map published in 1873,<sup>1</sup> after he had been two years in South Africa, adopted Bain's original succession. Mr. Dunn issued a second edition of his map in 1875,<sup>2</sup> and the additional two years' work confirmed his first views of the sequence.

In 1884, Professor Rupert Jones, in a paper to the British Association at Montreal, presented the Rubidge-Hochstetter view.<sup>3</sup>

In the same year, A. Moulle, a French engineer, who spent two years in this country, gave a general sketch of South African geology, in which he adopted Bain's succession for the formations in question.<sup>4</sup>

Mr. Dunn, in 1887, on the last edition of his map,<sup>5</sup> which may be regarded as a summary of his fifteen years' work in South Africa, again retained for the oldest formations the succession which he had at first adopted.

In the same year Professor Cohen, now of Greifswald, published the second part of his sketches of South African geology.<sup>6</sup> In dealing with the Ceres section, Cohen states that the Malmesbury slates and the greywackés of the Bokkeveld are different formations, but, not recognising the true character of the Witteberg Quartzite on the north of the Warm Bokkeveld, he places the Table Mountain Quartzites above the Bokkeveld Series, and agrees with Rubidge and Hochstetter as to the identity of those two quartzite series.

In 1888 Professor A. H. Green, who had visited South Africa in 1882 to report to the government of the Cape on the coals of the colony, published "A Contribution to the Geology and Physical Geography of the Cape Colony," in which he adopted Bain's succession for the above beds.<sup>7</sup>

Dr. A. Schenck, in the same year, came to the conclusion that the Table Mountain Sandstone, with which he classed the Zuurberg and Witteberg Quartzites also, and the Bokkeveld Beds were contemporaneous, his view being that the former were the shore equivalents of the latter.<sup>8</sup> This ingenious solution of the controversy is, however, unnecessary, and in the following year, 1889, Dr. G. Gürich, a countryman of Schenck, published a very convincing paper on the relationship of the disputed series, which he himself studied in the neighbourhood of Ceres, and unhesitatingly assigned to the positions to which Bain, Dunn, and Green had allotted them.<sup>9</sup>

While the work of Dunn, Green, and Gürich had virtually settled the correctness of Bain's original interpretation of the relationship of the four oldest formations, it was none the less

<sup>1</sup> Dunn, 25.

<sup>4</sup> Moulle, 68.

<sup>7</sup> Green, 88.

<sup>2</sup> Dunn, 26.

<sup>5</sup> Dunn, 27.

<sup>8</sup> Schenck, 80.

<sup>3</sup> Rupert Jones, 50.

<sup>6</sup> Cohen, 11.

<sup>9</sup> Gürich, 88.

gratifying that, at the beginning of the systematic geological survey of Cape Colony, which it was my privilege to inaugurate at the end of 1895, we were able to confirm the individuality of the Malmesbury Beds, the Table Mountain Sandstone, the Bokkeveld Beds, and the Witteberg Quartzites, as distinct series in this ascending order, with a marked unconformity beneath the Table Mountain Sandstone. We found also that, to a large extent, Bain was more correct than some of his successors as regards the mere distribution of the strata, and that his views of the structure of the country required amplifying more than correcting.<sup>1</sup>

Naturally a systematic government survey, with its continuity of work towards a definite goal, affords the best opportunity for solving structural problems, and, early in the history of the Cape survey, an important addition to our knowledge was made in the discovery by my then colleague, Mr. A. W. Rogers, that the Zwarteborgen are built up mainly of the Table Mountain Sandstone, which has been folded to form a second mountain chain, parallel and similar to the southern Langebergen.

The view formerly accepted was that the Zwarteborgen were built up of the same quartzites, which, north of Ceres, lie above the Bokkeveld Beds, and, further east, form the Wittebergen. These quartzites, however, play a comparatively small part on the northern slope of the mountains, beneath the shales which underlie the Dwyka Conglomerate. On Dunn's 1887 map the Zwarteborgen immediately north of Oudtshoorn are shown as composed of Table Mountain Sandstone, and, in the legend to that map, the name "Zwarteberg" is not, as in previous editions, associated with "Zuurberg and Witteberg" as a term for the upper series of the Cape system, so that we may consider that Mr. Dunn by that time had some inkling of the true state of affairs.

After two years' work of the survey we were enabled in the report for 1897 to give a map and a series of sections showing the distribution of the rocks and the general structure of the south-western districts of the Cape Colony, and to attempt some discussion of the general geological history of the region surveyed.<sup>2</sup>

During the years which have since elapsed, the survey has confirmed the succession then adopted for the older rocks, and greatly enlarged our knowledge of their distribution, and the part they play in the structure of southern and western Cape Colony. The results will be found adequately presented in the seven annual reports of the Geological Commission hitherto published, and I need here only refer to two interesting stratigraphical discoveries which have been made during these years.

First, the old rocks at Cango, near Oudtshoorn, given on

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<sup>1</sup> Corstorphine, 13.

<sup>2</sup> Rep. Geol. Com. for 1897, pp. 3-43.

Mr. Dunn's maps as Namaqualand Schists, proved to be different from those similarly designated near George and Worcester, which we found to be Malmesbury Beds. The Congo rocks consist of dolomite—similar to that occurring throughout the Transvaal—limestone, grits, slates, and sheared conglomerates. The latter contain boulders of granite, so that if the Congo rocks are contemporaneous with the Malmesbury Beds, they must have derived their boulders from some older granites than those intrusive in the Malmesbury Beds. If they got their granite boulders from the Malmesbury intrusions, then necessarily they are younger than these. Their true position is, however, doubtful, and we introduced the name "Congo Conglomerates" to distinguish them.<sup>1</sup>

Second, in 1900 the assistant geologists, Messrs. Rogers and Schwarz, discovered, in the Vaurhynsdorp district, a series of sandstones and slates lying unconformably between the Malmesbury Beds and the Table Mountain Sandstone. To this hitherto unrecognised series, the name "Ibiquas Beds" was given.<sup>2</sup>

#### THE OLD ROCKS OF NORTHERN CAPE COLONY.

In comparison with the progress made towards a full knowledge of the distribution, sequence, and relationship of the old rocks on the south and west, little has yet been done towards giving a clear idea of the Pre-Karoo rocks on the north of Cape Colony. Up to the present the geological survey has only been able to devote six months to the northern portion of the Colony, and the work was then limited to the interesting country, forming the basin of the Orange River, in the Hopetown and Prieska Districts.

The earlier accounts of the northern geology deal with special localities, and are scarcely sufficient to give one a comprehensive grasp of the region as a whole.

Namaqualand, with its copper mines, has naturally been frequently reported upon. A good account of the mines and their immediate neighbourhood was given in 1854 in a Government report by the then surveyor-general of the Cape, Mr. C. D. Bell.<sup>3</sup> In the following year Mr. Richard Bright,<sup>4</sup> in his later years magistrate at Stellenbosch, gave an interesting lecture on "Namaqualand and its mines," which he had himself visited. He speaks of the granite, syenite, gneiss, schists, and quartzite, extending from the coast inland to the mines, and, in one locality, Schaap River Mountains, he recognised certain quartzites as "Table Mountain Sandstone."

In the same year Delesse<sup>5</sup> wrote a paper, dealing chiefly with the mines, based on Bell's report and on specimens which had been sent to Europe. Delesse's geology cannot be regarded

<sup>1</sup> Report of the Geol. Com. for 1898, p. 7.

<sup>2</sup> Rep. Geol. Com. for 1900, p. 25.

<sup>3</sup> Bell, 8.

<sup>4</sup> Bright, 9.

<sup>5</sup> Delesse 16.

as specially authentic, since he placed Jurassic rocks somewhere on the Orange River.

In 1856<sup>1</sup> Wyley reported "Upon the nature and general character of the Copper Districts of South Namaqualand," but gave practically no geology.

One of Mr. Dunn's earliest reports to the Cape Government deals with Namaqualand and Bushmanland.<sup>2</sup> He describes the gneiss of the Orange River valley and the schists which he considers as lying above the gneiss. He also describes the "Namaqualand Schists (metamorphic)" of the Doornberg as consisting of jasper rocks rich in magnetite, schists, gneiss, and schistose conglomerates. The old rocks near Prieska he states to be "identical in character with and evidently a portion of the same formation as the old metamorphosed stratified rocks of Klein Namaqualand . . . their precise relation to the Malmesbury Beds underlying Table Mountain Sandstone remains yet to be worked out."<sup>3</sup> On each of his three maps Dunn gives a different interpretation to these rocks on the north of Cape Colony. On the first they are shown as Namaqualand Schists; on the second partly as Namaqualand Schists and partly as Malmesbury Beds; while on the last edition they are given as a portion of the Lydenburg Beds which lie above the Malmesbury Beds, and comprise, not only the rocks of Lydenburg, but practically the whole of the old rocks of the southern Transvaal, including what we now know as the Black Reef, Dolomite, and Gatsrand or Pretoria Series. It is a pity that Mr. Dunn gave no explanatory text with this map, for it would be interesting to know his grounds for placing these rocks, which cover so vast an area far removed from any of the typical southern rocks, between the Malmesbury and the Table Mountain Series.

Much detailed and accurate work was done on the north of Cape Colony by G. W. Stow. Self-taught, like Bain, Stow devoted his attention especially to the Province of Griqualand West, and also to the Uitenhage district. He was for a time geologist to the government of Griqualand West, and, at a later date, to that of the Orange Free State. In 1881, correspondence between him and the former government was printed by order of the House of Assembly of the Cape Colony, and the story of hardship and distress therein detailed by Stow, as resulting from the Government's treatment of him, does not redound to official credit. Stow, as early as 1873, tried to get the various South African governments to entertain a scheme for a geological survey of the entire region, and, according to the correspondence, the Legislative Council of Griqualand was enlightened enough to undertake a survey of the province without waiting for the co-operation of the neigh-

<sup>1</sup> Wyley, 105.

<sup>2</sup> Dunn, 22.

<sup>3</sup> Dunn, *loc. cit.* p. 8.

bouring states.<sup>1</sup> The results of Stow's survey were never officially published, but a valuable manuscript, containing probably the whole of his work, was some time ago presented to the Geological Society of South Africa by the late Dr. Exton, and may, under the auspices of that body, be one day published as a fitting memorial to a man whose life was sacrificed to science.

A portion of Stow's Griqualand West work, done apparently before he became official geologist, was published in the Quarterly Journal of the Geological Society, London, in 1874.<sup>2</sup> In a long paper, Stow describes various Griqualand West sections, and gives much detailed information with great accuracy. Perhaps the paper is overloaded with detail, and there is an absence of that broad generalisation which is so notable in Bain's work, but still Stow may justly be considered as second in order of merit among the earlier workers in South African geology.

In the paper to which I have referred, Stow describes the granite and gneiss of the district, as well as the other Pre-Karoo rocks, and, when Messrs. Rogers and Schwarz dealt with these rocks in the territory adjoining that described by him, they found his classification and sequence were a proper presentation of the facts.<sup>3</sup>

The rocks over this northern portion of Cape Colony cannot at present be correlated with those so well known on the south, and the classification of the sedimentary series, given in the report of the Geological Commission for 1899, was based as follows on that of Stow:—

1. Granite and Gneiss.
2. Keis Series—Quartzite and mica schists.
3. Doornberg Series { Griqua Town series—magnetic  
jasper rocks.  
Campbell Rand Series—Limestone  
and quartzite.
4. Matsap Series—Quartzites and conglomerates.

I shall refer later to the peculiarities of the old rocks on the north, compared with those on the south, when I treat of the general question of correlation. (*See p. 170.*)

#### THE ROCKS OF THE KARROO.

Owing to the clear natural division which exists, there has been no uncertainty, from Bain's time onward, as to the separation between the older rocks of South Africa and those which make up the Karroo and younger systems; but there has been much interesting discussion as to the origin and meaning of the strange conglomerate, which lies at or near the base of the Karroo System. Bain, as we have seen, described the conglomerate as a "Claystone porphyry," due to the activity of some

<sup>1</sup> Stow, 101. p. 4.

<sup>2</sup> Stow, 98.

<sup>3</sup> Rep. Geol. Com. for 1899, p. 68.



great volcano. Wyley adopted the same explanation, but, laying more stress than Bain on the included boulders, called the rock a "Trap-conglomerate."<sup>1</sup> Dr. W. G. Atherstone, famous afterwards as the first to decide that the crystal obtained by the trader O'Reilly was indeed a diamond, was also a supporter of the igneous theory. He described the rock as having "a felspathic fusible base, and assuming the appearance of a conglomerate or breccia, the included pebbles of granite, gneiss, quartz, slate, and sandstone, being sometimes angular, sometimes rounded, whilst in some parts of the Zuurberg it is vesicular, i.e., containing gas-bubbles which have been filled up with zeolites, agates, etc. It is not a true porphyry, although the base is porphyritic, but appears as if the molten lava in bursting up through the lower beds had broken up and mixed in its liquid paste the fragments of the different rocks it had passed through. From the description given by Darwin of the claystone-porphyrries and porphyritic conglomerates and breccias of South America running imperceptibly into each other, I should think the Zuurberg rock is of the same character, and may have been at times either an upheaving rock or a submarine lava poured out over the surface."<sup>2</sup>

Dr. P. C. Sutherland, of Natal, who was later to arrive at the true explanation, also at first took the rock to be a lava flow, and thought the striations underneath it were due to the movement of the igneous mass.<sup>3</sup> Ralph Tate in 1867 stated that the rock as exposed "on the flanks of the Zuurberg is decidedly a dolerite containing angular and rounded fragments of quartzite and granite," and then referred to it as "this Trap breccia."<sup>4</sup>

It was in 1868 that Sutherland in the following words first published what we now know to be the true explanation of the origin of this peculiar conglomerate:—

"the deposition of this formation cannot be accounted for except by reference to glacial action. It is by the action of glaciers, coast ice, and icebergs, and by it alone, that fine silt and boulders of many tons weight can be deposited simultaneously on the same sea or lake bottom. The great Scandinavian drift is precisely the same in mechanical composition as the boulder clay of Natal, with which we are now dealing. Professor Ramsay has assigned certain breccias of Permian age to glacial action; there is, therefore, no reason why our *quæstio verata* should any longer remain unsettled. . . . The sandstone on which this boulder formation rests is highly grooved and striated, as if clay or some semi-plastic substance containing hard fragments had passed

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Wyley, 107, p. 7.  
Sutherland, 102.

<sup>2</sup> Atherstone, 8, p. 587.  
<sup>4</sup> Tate, 104, p. 142, footnote.

“over it with considerable pressure. This may be seen at  
 “the Umgeni above the Queen’s Bridge, near the copper  
 “mines at the Ifumi, near Fort Buckingham at the Tugela,  
 “and, I was informed by His Excellency Sir George  
 “Grey, on the top of Table Mountain at the Cape of Good  
 “Hope.”<sup>1</sup>

I need hardly say that the last observation has not been confirmed.

Two years after Sutherland’s lecture Mr. C. L. Griesbach,<sup>2</sup> in what is still the best general sketch of Natal geology, described the peculiar appearance of the boulders as due to weathering. I do not know what Mr. Griesbach may now think, but in 1896, when I had the pleasure of meeting him in Cape Town, and discussing some of these geological questions with him, he did not accept a glacial origin for either the South African Dwyka, or the Indian Talchir, Conglomerate.

Moullé, writing fourteen years later, confirmed Griesbach’s description, but named the rock a melaphyre breccia.<sup>3</sup>

G. W. Stow, to whose important work on Griqualand West I have already referred, knew the glacial conglomerate there. He appears, however, to have been unable to view the glacial striae as of palaeozoic age, but regarded the ice-action as contemporaneous with the Great Ice Age of the northern hemisphere.<sup>4</sup>

In 1875 Mr. R. Pinchin described the conglomerate as metamorphic,<sup>5</sup> so there is no division of our petrographical classification into which some one or other has not placed this marvellous rock.

Mr. Dunn during his stay in this country wrote much about the conglomerate, and in the end he confirmed the correctness of the glacial explanation for all the outcrops in the Cape Colony. He seems to have first come across the conglomerate on the north of the Colony, east and west of Hope-town, in 1872. There, and at once he had no doubt of the glacial origin of the rock, but stated that “very scant material has been met with for determining the age of the conglomerate. It is probably older than the upper drift of Pniel classed as *P. Pliocene*.”<sup>6</sup> Professor Cohen, who, accompanied by Stow, saw some of these same outcrops in 1872, but did not describe them till 1887, was also of opinion that they were recent—Pleistocene, according to his view—though he did not see sufficient evidence for adopting a glacial explanation.<sup>7</sup>

On his first map (1873), Mr. Dunn showed these northern outcrops as “Glacial Conglomerate” at the top of his sedimentary sequence, but represented the whole band of conglomerate along the south of the Karroo as an igneous rock under

<sup>1</sup> Sutherland, 103, p. 18 and 17.

<sup>2</sup> Griesbach, 85.

<sup>3</sup> Moullé, 63.

<sup>4</sup> Stow, 97.

<sup>5</sup> Pinchin, 70.

Dunn, 22, p. 14.

<sup>7</sup> Cohen, 11, p. 273.



Wyley's name of "Trap Conglomerate." On the second edition (1875) Mr. Dunn still kept the two conglomerates separate, but introduced the name "Dwyka Conglomerate" for the outcrops on the south of the Karroo as well as for those in Natal.

In a report published in 1879, Mr. Dunn discussed the origin of the rock and there explained his reasons for introducing the non-genetic term, "Dwyka conglomerate," from its "characteristic occurrence near the river of that name." In this report he gave up the igneous explanation of the origin of the southern occurrences, stating that "the so-called trap conglomerate is as much a sedimentary rock as the sandstones above and below," and that, with the dark arenaceous shales below, it must be included in the Ecca Beds.<sup>1</sup>

The crowning stage of Mr. Dunn's investigation of this interesting rock was reached in the work which he presented in his "Report on a supposed extensive deposit of coal underlying the central districts of the Colony." On the sketch-map published to illustrate this report, Dunn showed the northern glacial conglomerate of his former maps, and the southern "Dwyka," as one continuous outcrop, and in the text he assigns both to a glacial origin.<sup>2</sup> In the last edition of his separate map published in the following year (1887), the same view is presented, and in the legend the "Dwyka Conglomerate" is described as glacial.

Dunn's work—conclusive though it should have been—did not at once gain general acceptance. Other geologists who visited South Africa without finding the definite evidence of glacial action which Sutherland and he had shown to exist in the Dwyka Conglomerate, were either unable to accept such an explanation of its origin, or denied altogether that the aspect of the rock was that of a glacial conglomerate. Thus, Professor Cohen simply stated that it was of clastic origin, and not a product of volcanic activity.<sup>3</sup> Professor Green thought it was a coarse shingle formed along a retreating coast-line, but if he had found the rock in a known glaciated country he indicates that his attitude might have been very different.<sup>4</sup> From the specimens which Green took home, Sir Archibald Geikie and Dr. Hatch both suggested that the rock had "the aspect of a volcanic breccia," an opinion which the latter author also held in 1898, and for which he then obtained support from Dr. J. W. Gregory.<sup>5</sup>

I believe that this last determination would almost invariably be given on examination of hand specimens, and perhaps even of microscopic sections, of the hard, compact, dark rock characteristic of the southern outcrops. It is only the striations on the included boulders which suggest the real nature of the rock, and one can rarely recognise these on the smaller pebbles

<sup>1</sup> Dunn, **23a**, pp. 6 and 8.

<sup>2</sup> Dunn, **24**.

<sup>3</sup> Cohen, **11**, p. 208.

<sup>4</sup> Green, **33**, p. 243.

<sup>5</sup> Hatch, **40**, pp. 94 & 100.

of an ordinary hand-specimen. The difficulty in determining the southern rock as glacial, and not volcanic, is brought home to one in the fact that both Sutherland and Dunn maintained its igneous origin, before they were convinced of its true character.

Dr. A. Schenck, now of Halle, writing in 1888, held the Dwyka to be glacial, but considered that its identity with the outcrops of glacial conglomerate in the north of Cape Colony was still doubtful<sup>1</sup>

Dr. F. M. Stapff, an engineer and a countryman of Schenck, entered into the controversy in the following year, 1889, and gave an anti-glacial explanation for all the southern conglomerate outcrops, and, only to a limited extent, accepted glacial action for the northern rock.<sup>2</sup> Schenck replied, and, more emphatically than in his earlier paper, assigned to the Dwyka as well as the northern conglomerate a glacial origin, and was then disposed to admit their identity.<sup>3</sup>

In 1893 Mr. A. R. Sawyer reported to the Cape government on the geology and mineral resources of the division of Prince Albert, where he saw good outcrops of the typical southern Dwyka and described it as a "sedimentary rock." From its occurrence in the field, and examination of the matrix in thin section under the microscope, he took it to be "undoubtedly a volcanic ash mixed no doubt in part with other fragmentary materials derived from the operation of moving water."<sup>4</sup>

The next observation recorded of the southern Dwyka was by my former colleague, Mr. E. H. L. Schwarz,<sup>5</sup> of the Cape survey. Mr. Schwarz, in 1896, obtained in the small basin of Dwyka Conglomerate, north of the Gydo Mountains, Ceres, undoubted glacially faceted and striated boulders, which are now exhibited in the South African Museum, Cape Town. In the following years we all found glaciated boulders in the Dwyka, at various localities along the southern boundary of the Karroo, as Mr. Dunn had in earlier years. In fact, the glacial theory was the only one to which, from the beginning, the survey results gave any support. As, however, all the outcrops, with which we became familiar on the south, showed the conglomerate and its occasional shale beds, conformably interbedded between the Witteberg quartzites and the Eccra shales, the source of the ice-worn stones remained as much a mystery as ever.

In 1899, as I have said, the survey was carried on by Messrs. Rogers and Schwarz in the Prieska and Hopetown divisions on the north of the Colony. There the rock, originally named Glacial Conglomerate by Mr. Dunn, and afterwards linked up by him as identical and continuous with the southern Dwyka Conglomerate, was studied in some detail.<sup>6</sup> In his 1886 paper, Mr. Dunn correctly described the older

<sup>1</sup> Schenck, 80.

<sup>4</sup> Sawyer, 79, p. 4.

<sup>2</sup> Stapff, 95

<sup>5</sup> Rep. Geol. Com., 1896, p. 36 (8vo. ed.).

<sup>3</sup> Schenck, 82.

<sup>6</sup> Rogers and Schwarz, 78.

rocks in the Hopetown district as grooved and striated underneath the conglomerate, and ascribed the phenomena to the grounding of icebergs, which he considered were also responsible for the formation of the entire conglomerate.<sup>1</sup> The result of the 1899 work of the Cape survey, was, however, to show that there is a distinct difference in the character and relationship of the northern, compared with the southern, conglomerate outcrops—the northern rock lying unconformably on much older rocks instead of conformably in its natural sequence. When I discussed the results of the work, I could only conclude that we had to deal on the north with a true ground-moraine on the site of the ancient glacier, while the southern Dwyka represents the silt and boulders carried southward by floating ice, and spread over the floor of the great inland sea which in late carboniferous times occupied the site of the now arid Karroo.<sup>2</sup>

Since the early descriptions by Bain and Wyley, the ordinary sedimentary rocks of the Karroo and their fossils have been described and classified chiefly by Tate, Rupert Jones, Dunn, Green, Feistmantel, and Seeley. The interest of the Karroo stratified rocks is palaeontological, much more than geological. When one passes from the area which has been implicated in the great foldings that produced the Zwarteborgen, one finds only a series of horizontal or gently dipping sandstones and shales without any outstanding structural features. Even the palaeontological interest is limited to scattered localities, for one may examine extensive areas, and considerable thicknesses of strata, without finding any trace of organic remains; in fact, the sparseness of fossil localities—quite as much as of fossil horizons—in South African rocks generally, always strikes one as peculiar.

Professor Rupert Jones gave a sequence for the Karroo strata in 1867, in a paper by Ralph Tate<sup>3</sup> on certain species of South African fossil plants which had been collected and presented to the Geological Society by Atherstone, Rubidge, Sutherland, and others. The various divisions are named from below upwards, as:—

1. Ecça Beds, in an “upper and lower series separated by, and lying conformably with, the remarkable band of igneous rock which extends across South Africa” [i.e., the Dwyka Conglomerate].
2. Koonap Beds.
3. The Beaufort Beds.
4. The Stormberg Beds.

Mr. Dunn did a good deal of work for the Cape government in connection with various mineral occurrences at different horizons in the Karroo System, and made a detailed survey of the Stormberg Beds in the Molteno neighbourhood in

<sup>1</sup> Dunn, 24, p. 6.

Rep. Geol. Com. for 1899, p. 27.

<sup>3</sup> Tate, 104.

1878.<sup>1</sup> In his various reports he makes practically no change in his original Karroo sequence, but he altered his first expressed opinion as to the relationship of the upper and lower beds, which he had at first thought unconformable. In his 1886 report, the last one to the Cape government, Mr. Dunn concluded that, in the entire Karroo System, from the Dwyka Conglomerate to the Stormberg Beds, there appeared "to be no break or want of conformity whatever,"<sup>2</sup> a view quite in accord with our present knowledge.

In 1883, and again in 1888, the late Professor A. H. Green<sup>3</sup> discussed the Karroo Beds, which he placed in five groups:—

Stormberg Beds,  
Karoo Beds,  
Kimberley Shales  
(*great unconformity*),  
Ecca Beds,  
Dwyka Conglomerate  
(*unconformity*).

He considered that the northern shales were distinct from the southern, and, under the name of Kimberley shales, he placed them unconformably above the Ecca Beds. Green correlated his Kimberley shales with Stow's olive shales, and regarded Stow's "Ancient Conglomerate" at the base of these shales, as something different from the Dwyka, with which he suspected it had been confounded. We now know that the Kimberley shales and the conglomerate beneath them are, as Dunn held, identical with the Ecca Beds and their basal conglomerate.

The best discussion of the Karroo System and description of its fossil flora, which I know, was published by Dr. Ottokar Feistmantel in 1889.<sup>4</sup> Feistmantel begins his invaluable paper with a *catalogue raisonné* of the chief literature, he next deals critically with various authors' views of the classification and sequence, not only of the Karroo but also of the underlying systems, and then gives what—until Mr. Seward began his work on South African fossil floras—was certainly the best account of the Karroo plants. Feistmantel's views are particularly interesting in virtue of his experience in India, and his knowledge of the Australian fossil floras. In an earlier paper<sup>5</sup> he had also dealt with the comparative geology of the three regions, and one can only regret that he did not live to complete his descriptions of the South African plant fossils. Feistmantel arranged the Karroo beds in three groups—a lower, including the Dwyka conglomerate and the Kimberley-Ecca Shales, which is certainly the best classification of these lowest beds, a middle including the Beaufort Beds, and an upper comprising the Stormberg Beds. From the determination of the plant remains Feistmantel correlated the Storm-

<sup>1</sup> Dunn, 22.

<sup>2</sup> Dunn, 24, p. 5.

<sup>3</sup> Green, 82, 88.

<sup>4</sup> Feistmantel, 29.

<sup>5</sup> Feistmantel, 28.

berg Beds as probably equivalent to the Lias and Rhaetic; the Beaufort to the Trias; and the lowest division to the Permian-carboniferous of the northern hemisphere.<sup>1</sup>

Professor H. G. Seeley has given, incidentally in his series of monumental papers on the Karroo Reptilia, a division of the system into zones in accordance with the distribution of the remains of these peculiar vertebrates. He proposed, in 1892, a five-fold division of the entire system from above downwards, thus<sup>2</sup> :—

5. Zone of the Zancloodonts.
4. Zone of the Specialised Theriodonts.
3. Zone of the Dicynodonts.
2. Zone of the Pareiasaurians.
1. Zone of the Mesosaurs.

Enough work on the Karroo has now been done by the Cape survey to permit of an outline classification of the beds, and Mr. Rogers gave such in his report for 1902. (*See chart.*) In the classification of this system I think it is a pity that the separation of the Dwyka as a "Series," which I adopted in 1897, should still be maintained; for the subsequent work in the Cape Colony, and the observations I have made in the Transvaal, indicate that the original classification of the Dwyka, as a portion of the Ecca Series, is the best representation of the facts.

Quite recently Mr. A. C. Seward has described the fossil plants collected by the survey in the lowest and uppermost divisions of the Karroo system, and been able to confirm Feistmantel's tentative correlation of the Stormberg Beds with the Rhaetic of Europe.<sup>3</sup>

Further stratigraphical work on the Karroo System will probably take the form of more minute classification of the enormous thickness of beds, on the basis of their fossil contents, but this is not a matter of any immediate importance, and, when attained, will not alter our views of the general succession.

It would be out of place to deal here with the interesting types of igneous rocks which occur among the Karroo sediments in the form of dykes, sheets, and necks; but it seems fitting to refer to the valuable contribution which Cohen has made to our petrographical knowledge of these rocks, for it is to him that we owe our earliest and still most extensive series of papers on South African petrography.

#### NATAL STRATIGRAPHY.

Natal geology is discussed in several of the papers already mentioned, notably those of Sutherland, Griesbach, and Schenck, and is also presented on the 1875 and 1887 maps of Mr. E. J. Dunn. All of these writers naturally made comparisons and correlations with the formations of the Cape, for to

Feistmantel, 29, p. 75.

<sup>2</sup> Seeley, 86.

<sup>3</sup> Seward, 89.

a large extent Natal and Cape Colony are geologically alike, and there is little difficulty in instituting reasonable comparisons. The older Natal rocks, however, resemble those of the Transvaal, rather than those of the Cape, in being, so far as yet known, devoid of all organic remains, and there is accordingly some difficulty in attaining detailed correlations.

Mr. William Anderson, who was appointed Government Geologist of Natal in 1898, has in his first report<sup>1</sup> dealt with the question, and rightly refused, for the time at least, to adopt a close correlation of the Pre-Dwyka sediments of Natal with those of the Cape, preferring to refer to them simply as Palæozoic sandstones. Mr. Anderson agrees with earlier writers that these sandstones rest unconformably on the granite and metamorphic rocks, which, he states, form the oldest rocks of this part of South Africa. The survey which Mr. Anderson has already made of the Natal rocks has shown him that there is not only the unconformity beneath the Dwyka, which Sutherland recognised, but also a slighter one above the same formation. This brings the Natal glacial conglomerate into line with that of northern Cape Colony and the Transvaal. From Mr. Anderson's researches the age of the Natal coal beds appears also to correspond to that of the Ecca beds of the Cape, and not to the Stormberg. The Stormberg Series is, however, well developed in the Drakensbergen, the various divisions being easily recognisable through the Transkeian Territories into Natal, and a perfect correlation with the typical sequence of the Cape can be accepted.

The Natal coastal cretaceous rocks are dealt with in the next section.

#### THE COASTAL CRETACEOUS ROCKS.

A marked geological feature in South Africa is the comparative absence of rocks, corresponding to the later Secondary and Tertiary Systems of other parts of the world.

The recent work of Mr. A. C. Seward on the flora of the Stormberg Beds, has confirmed Feistmantel's determination of these as Rhaetic. Except, therefore, a considerable variety of superficial deposits—the origin of some of which certainly dates back to Tertiary times—we have no rocks other than those occurring, over comparatively limited areas, at Mossel Bay and the neighbouring inland districts of Oudtshoorn and Worcester, at Uitenhage, and on the Pondoland, Natal, and Zululand Coasts, to represent the great lapse of time indicated by the Jurassic, Cretaceous, and all the Tertiary Systems of other parts of the world.

The earliest account of these coastal deposits which I know, was given in 1837 by Hausmann,<sup>2</sup> who described a suite of fossils sent him from Enon and Uitenhage by a Mr. Hertzog.

<sup>1</sup> Anderson, 2.

Hausmann, 45.



As a result of his determination of the fossils, Hausmann correlated the formation with the Lower Greensand of Europe.

In 1843, and again more comprehensively in 1845, Dr. Ferdinand Krauss,<sup>1</sup> of Stuttgart, gave the geological results of a visit he had made to the eastern portion of Cape Colony, where these beds occur. He also said that the rocks "probably belong to the Lower Greensand."

Bain described the beds which occur near Uitenhage, and came to the conclusion that they had more of an "oolitic than a liassic character."<sup>2</sup>

Sharpe, who described the secondary fossils collected and sent home by Bain and Atherstone, stated that "the forms which they most nearly resemble are those which are found in the middle and lower part of the Oolitic Series." He considered that Bain placed the beds too low in comparing them to the Lias, but Krauss' view that they were Cretaceous "seemed to rest on still weaker grounds."<sup>3</sup>

The Uitenhage Beds were described and classified by Dr. W. G. Atherstone<sup>4</sup> in 1854, and, in 1867, Ralph Tate<sup>5</sup> adopted Atherstone's classification of the beds in his description of a representative suite of their fossils, which had been collected by Drs. Atherstone and Rubidge, Messrs. Longlands, Harvey, and Rock, and presented to the London Geological Society.

Tate in his paper introduced the name "Uitenhage formation," and concluded "that the fauna of the strata (Trigonia-beds) overlying the plant-bearing beds of Geelhoutboom presents a decided Oolitic facies; and, although few species are common to these South African strata and the European Oolites, yet from the large number of species in these strata at Uitenhage having analogues in the Lower and Middle Oolites, and the species in common pointing in the same direction, the fossil fauna of the Sunday's River and Zwartkop River limestones represents that of the Oolitic rocks of Europe, and approximates to that of the Great Oolite."<sup>6</sup>

Stow, in his usual minute careful manner, gave in 1871 an account of the "Jurassic Formations."<sup>7</sup> He described a series of sections with the fossil contents of each zone, and showed conclusively that there is great variation in the sequence of beds in this formation.

In a paper published in 1881, Neumayr, after describing various new mollusca from the Uitenhage formation, and reviewing the work of his predecessors, returned to the view that the Uitenhage formation is Cretaceous, and placed it parallel with the Neocomian.<sup>8</sup>

<sup>1</sup> Krauss, 51, 52.

<sup>2</sup> Bain, 6, p. 185.

<sup>3</sup> Sharpe, 91, p. 202.

<sup>4</sup> Atherstone, 8.

<sup>5</sup> Tate, 104.

<sup>6</sup> *Loc. cit.* p. 167.

<sup>7</sup> Stow, 97.

<sup>8</sup> Holub and Neumayr, 47.

On his 1887 map Mr. Dunn shows the distribution of these beds, under the name "Enon Conglomerate and Sunday River Beds, Jurassic," at Worcester—their most westerly occurrence—at Oudtshoorn, Mossel Bay, and Uitenhage.

Mr. R. Bullen Newton, in 1896,<sup>1</sup> describing a specimen of *Alectryonia ungulata*, found by Mr. David Draper at Sofala, gave a critical review of the previous descriptions of the Uitenhage fossils, and concluded that these were of Lower Cretaceous, or Neocomian species.

During the first years of the Cape survey we found the Uitenhage beds well represented in the south-western districts from Worcester to Mossel Bay. Their unconformable relation to the older rocks was everywhere apparent—an especially fine section being afforded at Cape St. Blaize, where Enon Beds lie almost horizontally on steeply dipping Table Mountain Sandstone.<sup>2</sup>

In 1899, Mr. Schwarz made the interesting discovery that some of the Enon Beds at Knysna contain *Trigonia*,<sup>3</sup> and, in the following year, he and Mr. Rogers mapped a considerable extent of the formation in the original locality around Uitenhage.<sup>4</sup>

The fossil plants collected by Messrs. Rogers and Schwarz, in the various localities mapped by them, have recently been described by Mr. Seward, and as a result he has confirmed the earlier determinations of the age of the series as Lower Greensand.<sup>5</sup>

On the coast of Pondoland, south-west of the Umtamvuna River mouth, are certain outcrops of Cretaceous rocks, which have been known, and recognised as such, since 1855. The rocks were then briefly described by R. J. Garden, whose collection of the fossils was described by W. H. Baily. Garden states that the rocks were discovered by H. F. Fynn in 1824. Baily concluded that the Beds were probably the equivalent of the Upper Greensand of England.<sup>6</sup> The next description of these beds was given by Mr. Griesbach,<sup>7</sup> who, in addition to the localities where Garden found them, also mentions the "bed of a small stream flowing into the St. Lucia Bay, in the Zulu country."<sup>8</sup> Griesbach used the somewhat impossible name, "Izinhluzabalungu" beds for the Pondoland occurrence, this, according to Captain Garden, being the native name—meaning "the houses of the white men"—for certain caves in the formation. Griesbach described the rocks as lying unconformably on the Karroo formation, and considered that there were five distinct fossil zones. Among the fossils he found considerable resemblance to those occurring in Indian rocks of the same age. Dunn, on his 1887 map, shows

<sup>1</sup> Newton, 64.

<sup>2</sup> Report Geol. Com. 1898, p. 18.

<sup>3</sup> Schwarz, 85.

<sup>4</sup> Rogers and Schwarz, 74.

<sup>5</sup> Seward, 89.

<sup>6</sup> Garden, 80, Baily, 4.

<sup>7</sup> Griesbach, 85.

<sup>8</sup> *Loc cit.* p. 61.



two patches of these rocks, on the Pondoland and Natal coasts, which he names "Umtamvoona Beds," and classifies as cretaceous. In 1900 Messrs. Rogers and Schwarz described the Pondoland cretaceous rocks. They found that there had been considerable change in the outcrops of these rocks since Garden's and Griesbach's descriptions: instead of eight hundred yards of caves they found that the line extended for a mile: on the extreme end of the left bank of the Umzamba River, where Garden had found the fossiliferous rocks, they saw only sand. They found that the fossils are not in defined zones as Griesbach had thought, but that the majority of the species are distributed throughout the entire thickness—only some twenty feet—of exposed rock.<sup>1</sup>

In the first report of the geological survey of Natal and Zululand, Mr. Anderson describes the cretaceous rocks from three localities in Zululand: one on the south bank of the Umfolosi River, close to Lake Isitesa; another on the Umsinene River, which he identifies with Griesbach's St. Lucia Bay locality; and a third in the bed of a stream, "about two miles east of Crossly's store, Bombeni, near the southern end of the Lebombo Range." Mr. Anderson is of opinion that the formation is much more largely present than the outcrops indicate, but is hidden by the overlying sands. He made a collection of the fossils, which are to be described by Mr. R. Etheridge, Junr.<sup>2</sup>

#### TRANSVAAL STRATIGRAPHY.

Turning now to Transvaal stratigraphy, we find that geological inquiry here has the same history as in the Cape Colony: first the observations—sometimes of scientific value, sometimes purely casual—of the passing traveller; then the work of those with opportunity for more thorough study, whether as local amateurs, or as professional visitors to some area of real or supposed economic value; then finally the systematised work of a state survey. Controversy over the larger questions has never been so acute as in Cape Colony, but as the identity or non-identity of reefs has generally been the main question when dispute did arise, there has been room for much difference of opinion, with a corresponding difficulty for the disputants to remain coldly scientific. The geology of the Cape Colony being comparatively well known when that of the Transvaal began to be studied, most writers have naturally been tempted to draw comparisons between the two regions, thus unfortunately producing much confusion and but little scientific result. It is, of course, since 1886 that most attention has been given to Transvaal geology; but before that time the gold fields of Lydenburg and De Kaap, and the coal deposits of the southern Transvaal, had given occasion for the visits of such men as Cohen and Penning, who

<sup>1</sup> Rogers and Schwarz, 75.

<sup>2</sup> Anderson, 2, p. 47.

both made contributions toward the elucidation of the stratigraphical problem.

Of the earlier travellers, who have given geological information about the Transvaal, I may mention Mauch<sup>1</sup> and Hübner.<sup>2</sup> Mauch has many scattered geological observations throughout the story of his wanderings; and Hübner, giving a geological sketch of his route from Potchefstroom to Inyati and then north to Tati, describes chiefly the old granite and its associated rocks. He recognised that the "red eruptive rock of the Pilandsberg" was younger than any of the other rocks which he saw.<sup>3</sup>

After Hübner, Penning, so far as I can learn, was the next to attempt—if only partially—the stratigraphical problem. In 1884 and 1885, he read two papers before the London Geological Society dealing respectively with the "High Level Coal-fields," and the "Gold-fields of Lydenburg and De Kaap." He described the coal formation as resting on rocks of "probably Upper Palaeozoic age, the Megaliesberg Beds." To the shales forming the lower part of the coal formation he applied the name Kimberley Beds."<sup>4</sup>

In his second paper Penning gives, for the district with which he deals, the following sequence:—<sup>5</sup>

4. High Veldt Beds [= the coal formation].
3. Devonian ? rocks [= { Magaliesberg Beds, including the dolomite, which he called chalcedolite].
2. Silurian ? rocks.
1. Granitic ? rocks.

E. J. Dunn, on his map of 1887, to a much greater extent than on either of the previous editions, presents a distribution of the rocks of the Transvaal, and their correlation with those of Cape Colony, but in both respects this portion of the map has not the same value as has his representation of the geology of the latter colony.

Dr. Schenck discussed Transvaal stratigraphy in his paper of 1888,<sup>6</sup> and to a less extent in one on the "Occurrence of gold in the Transvaal" written in the following year.<sup>7</sup> He classified the Transvaal rocks in the same main groups as those of Cape Colony, namely:—

3. Karrooformation.
2. Kapformation.
1. Südafrikanische Primärformation.

In the first group Schenck placed the granite and gneiss with his "Swasi Beds," the latter including the clay-slates, quartzites, and striped magnetic slates near the base of the Witwatersrand Series. He united the rocks of the Magaliesberg with those of the Witwatersrand, and correlated both with the

<sup>1</sup> Mauch, 54.

<sup>2</sup> Hübner, 48.

<sup>3</sup> *Loc. cit.* p. 424.

<sup>4</sup> Penning, 67, p. 659.

<sup>5</sup> Penning, 68, p. 570 *et seq.*

<sup>6</sup> Schenck, 80.

<sup>7</sup> Schenck, 81.

Table Mountain Sandstone and Bokkeveld Beds, which in his opinion were equivalent facies. Schenck's classification of the Transvaal rocks has been more or less followed by subsequent writers, but it is to be deprecated that his correlations should so often have been accepted as proved facts, when they were merely reasonable attempts to give as comprehensive a view of the geological knowledge of sixteen years ago as was possible.

Dr. G. A. F. Molengraaff first visited South Africa in 1890 in which year he had published, in Dutch, a non-critical résumé of the then existing views regarding South African stratigraphy.<sup>1</sup> The results of his own visit, which lasted some two months, were briefly given in a lecture to the Third Congress of Naturalists and Chemists at Utrecht, in 1891,<sup>2</sup> and three years later, in more complete form, as a paper in the *Neues Jahrbuch*.<sup>3</sup> In the latter, Dr. Molengraaff bases his classification on that of Schenck, but gives more detail. The lowest Witwatersrand Beds are separated from the upper as the "Old Schist formation," with an unconformity above and below, and to this series the magnetic quartzites and slates of the Magaliesberg are assigned—a grouping which Schenck had also given. The classification given in this paper was abandoned by its author, when later, as State Geologist, he had had opportunity for more extended and more systematic stratigraphical investigation.

In 1891 Penning made a further addition to his previous classification. One of his main groups, the "Megaltiesberg formation, Permian," includes the Witwatersrand Beds, and his "Klipriver Series," which embraces the Black Reef, the Dolomite (which he called "Chalcedolite"), and the "Megaltiesberg quartzites." He recognised that the only formation that could be approximately classified was the newest of all, that which in 1884 he described as the High-level Coalfields of South Africa, and which he took to be of Oolitic age. In his 1885 paper, Penning speaks of an unreliable report of graptolites having been observed in his "Silurian?" rocks,<sup>4</sup> and in the 1891 paper he states that he believes his provisional De Kaap Valley Beds "to be of Silurian age, although there is no fossil evidence except that of a few obscure Corals."<sup>5</sup>

In 1894 Mr. David Draper gave a geological description of south-eastern Africa,<sup>6</sup> including the colony of Natal, Zululand and Swazieland, the south-eastern Transvaal, and the eastern portion of the Orange Free State and Basutoland. The bulk of the paper gives an account of the Karroo Beds, including the Dwyka Conglomerate, which the author inclined to believe showed as much evidence of igneous as of aqueous origin. He quotes the opinion of Dr. Molengraaff, who had "studied

<sup>1</sup> Molengraaff, 55.

<sup>4</sup> Penning, 69, p. 452.

<sup>2</sup> Molengraaff, 56.

<sup>5</sup> Penning, 69, p. 571.

<sup>3</sup> Molengraaff, 57.

<sup>6</sup> Draper, 19.

the rock both *in situ* and by means of microscope sections," to the effect that it is "a volcanic tuff (a probably Permian diabase tuff), full of fragments of older rocks."<sup>1</sup> The old rocks are described as "Primary Rocks," consisting principally of Table Mountain Sandstone resting unconformably on Malmesbury Schists, the latter comprising schists, slates, quartzites, granite, and gneiss. The general classification which Mr. Draper gives is interesting, in that he regards the Bokkeveld Beds as wanting in the Transvaal, but he indicates their position as being underneath the "Malmani Limestone (Dolomite)."

Two years later,<sup>2</sup> Draper gave a description, classification, and correlation of the "Primary systems of South Africa." He amplifies his previous sequence by the insertion of the Lydenburg Beds (Dunn) and Swasi Beds (Schenck) above the Malmesbury Beds, and the correlation, suggested by Professor Rupert Jones in a foot-note to the previous paper, of the Magaliesberg and Gatsrand quartzites with those of the Zwarteberg and Witteberg of the Cape. Mr. Draper places a slight unconformity beneath these, another beneath the dolomite, and a great unconformity beneath the Table Mountain Sandstone, with which he correlates the Witwatersrand conglomerate series.

In a lecture given in London in the same year, 1896, Mr. Draper<sup>3</sup> classified the older Transvaal rocks thus, from above downward:—

1. { Gats Rand Beds.  
Dolomitic limestone with Black Reef Quartzite.  
(Unconformity).
  2. { Quartzites and slates with  
massive conglomerate } Table Mountain Sandstone.  
beds interstratified.
  3. Quartzites and shales without Conglomerate beds.
- Archaean. { Namaqualand Schists.  
Granitic rocks.

In 1898 Dr. F. H. Hatch published "A Geological Survey of the Witwatersrand and other districts in the southern Transvaal."<sup>4</sup> In his classification he also adopted the divisions introduced by Schenck: 1, Archaean; 2, Cape System; 3, Karroo System. The Archaean system comprises the granite and the crystalline schists; the Cape system includes five series of beds, from the Hospital Hill Series to the quartzites of the Magaliesberg and Gatsrand, with a division, into upper and lower, between the Klipriversberg Amygdaloid and the Witwatersrand Beds. In this paper Dr. Hatch confirms Penning's original and, as we know, correct view that the Magaliesberg Beds are the same as those of the Gatsrand, and not, as Schenck and Molengraaff had held, identical with those of the Witwatersrand. Dr. Hatch's paper gives a clear view of the suc-

<sup>1</sup> Draper, *loc. cit.* p. 555.

<sup>2</sup> Draper, 20.

<sup>3</sup> Draper, 21.

<sup>4</sup> Hatch, 40.

cession, though not of the grouping, as we now accept it. The position of the Klipriversberg Amygdaloid as a flow unconformably beneath the Black Reef is correctly given, though at that time Dr. Hatch had not seen evidence to prove its unconformity upon the Witwatersrand Beds, as he himself has since pointed out.<sup>1</sup>

Dr. Molengraaff began work as State Geologist of the Transvaal in September, 1897, and his first report gives the results of his work for the remainder of the year.<sup>2</sup> In this first official publication, a "preliminary report on the succession of the formations in the southern half of the South African Republic" is given. The author adopts, for the lowest sub-division, the name, "South African Primary Formation or Barberton Formation," which includes:—

- "1. Granite and Schists.
- "2. Hospital Hill Series, including Hatch's Hospital Series and Gibson's lower Quartzite Group, as well as a large portion of Schenck's Swazi Schists.
- "3. The Witwatersrand Series—the exact position of which in the general system has not yet been satisfactorily determined."<sup>3</sup>

Dr. Molengraaff approved of Schenck's term, "Cape System," as applied to the Black Reef, Dolomite, and Magaliesberg or Pretoria Beds, which he correlated respectively with the Table Mountain Sandstone, the Bokkeveld Beds, and the Witteberg Beds of the Cape. In this report the Magaliesberg Beds are placed in the position to which Penning and Hatch had previously assigned them. Of the Karroo System in the Transvaal, only the coal-bearing sandstone is dealt with, and that is placed parallel with the Stormberg Beds of the Cape Colony.

The second and last report<sup>4</sup> of Dr. Molengraaff as Transvaal State Geologist gives the results of the work carried out in 1898—results bearing conspicuous testimony to their author's energy and enthusiasm. In this report the South African Primary System is given virtually as in the previous report, but the author states that absolute certainty regarding the relation of the schists to the Barberton Formation has, however, not been established.<sup>5</sup> The Cape System is enlarged by the provisional inclusion, in ascending order, of two hitherto unrecognised series, the "Red Granite" and the "Waterberg Sandstone." This "Red Granite" had generally been confused with the "Old Granite," though Hübner recognised that the red rock of Pilandsberg was much younger than the latter.<sup>6</sup>

The work of the Transvaal geological survey under the republican government was cut short in 1899 by the war, but in 1901 Dr. Molengraaff published the results of his previous

<sup>1</sup> Hatch, 42.  
Molengraaff 59.

<sup>2</sup> Molengraaff, 58.  
<sup>5</sup> Molengraaff, *loc. cit.*, p. 3.

<sup>3</sup> *Loc. cit.* p. 123.  
<sup>6</sup> Hübner, 48, p. 424.

work, with an accompanying map, in the Bulletin of the Geological Society of France.<sup>1</sup> This is the most comprehensive account of Transvaal geology which we at present have. The sequence given in it does not present any essential difference from that given by the author in his 1898 report. Dr. Molengraaff takes the Barberton Series, of which the Hospital Hill and Witwatersrand Series are held to be local modifications, as the oldest formation, into which he considers the old granite to be intrusive. The "Red Granite," with its associated norite and porphyritic rocks, is now classified as the "Plutonic Series of the Bushveld," and regarded as a great laccolite, once covered by Waterberg Sandstone, instead of as a flow intermediate in age to the Pretoria and Waterberg Series.

We may say that, thanks to the work of the many geologists to whom I have referred, and especially to that of Molengraaff and Hatch, the main divisions and sequence of the Transvaal rocks have been made out, though there are many questions of distribution and local relationship still to be solved. The period which has elapsed since the war ceased has not been unfruitful in geological results, as the Transactions of the Geological Society of South Africa testify. The chief stratigraphical facts which have been brought to light during this period are:—

(1.) The recognition that beneath the Black Reef Series we have an extensive formation, resting unconformably on the Witwatersrand Beds, and consisting, not only of the well-known amygdaloids, of which those of the Klipriversberg may be taken as typical, but also of a series of conglomerates, grits, volcanic breccias, tufas, and banded cherts.

(2.) The fact that the Witwatersrand Beds are not older than, but rest unconformably upon, the old granite, has been again insisted upon. This is a return to the view held by Gibson,<sup>3</sup> Hatch,<sup>4</sup> and Penning,<sup>5</sup> which, however, has been latterly replaced by the opinion, urged chiefly by Dr. Molengraaff, that the granite is intrusive in certain schists held to be part of the Witwatersrand Series.

(3.) The discovery that the Waterberg Sandstone is not conformable to the older underlying rocks, has been made by several workers independently in different localities. Mr. Dörffel has already published the fact as an inference from the position of the cobalt lodes in the Balmoral District;<sup>6</sup> Mr. E. Jorissen found the Waterberg Sandstone resting unconformably on Pretoria Beds in the Rustenburg District; Mr. E. T. Mellor found the same relationship near Pretoria; and I myself found the Waterberg conglomerates and quartzites resting directly on the old granite, on the northern and southern slopes of the Zoutpansberg.<sup>7</sup>

<sup>1</sup> Molengraaff, 61.      <sup>2</sup> Hatch, 43; Molengraaff, 62; Corstorphine, 14.

<sup>3</sup> Gibson, 81.      <sup>4</sup> Hatch, 40.      <sup>5</sup> Penning, 69.      <sup>6</sup> Dörffel, 17.

<sup>7</sup> Since the above was written the observations of Messrs. Jorissen and Mellor have been published in the Trans. of the Geol. Soc. of South Africa, Vol. VII.



Most promising of all for the systematic investigation of the many interesting geological problems of this country, the survey has been re-established, and we look forward with interest, and with the certainty of valuable result, to the first annual report which the Director, Mr. Kynaston, will shortly present to the government.

#### THE CORRELATION OF THE FORMATIONS IN THE SEVERAL COLONIES.

The main stratigraphical question now awaiting solution in South Africa is the correlation of the formations in the various colonies. It is not a problem to which a definite answer can be immediately given; we are not yet able to do much more than formulate reasonable working hypotheses, or, in some instances, simply to state the case. We are dealing with an enormous area of country, and are bound to recognise that we are not yet justified in assuming that we know all the formations present in South Africa. Even if we could assume this, it is probable that definite correlations would not, as regards some of the groups, be possible, and that we must wait till they are virtually joined up by actual survey.

The absence of fossils throughout the greater portion of the sedimentary rocks of South Africa is a striking feature, not easily explicable. It renders correlation, not only with foreign strata, but even between the individual members of the sequence in the various portions of this country, extremely difficult. So far as I know, the records of fossils from the Pre-Karoo rocks, outside of Cape Colony, are limited to the casual remarks of Penning which I have already quoted (see p. 166); the observation by Professor Cohen that, on the weathered surface of the dolomite near the Makwassie Spruit, between Klerksdorp and Potchefstroom, he found impressions of crinoids, and of brachiopoda resembling *Orthis* and *Chonetes*;<sup>1</sup> the statement by Griesbach that in a soft shale band in the Table Mountain Sandstone of the Krantzkop, Natal, he found some bivalves and a finely striated *Patella*, both too indistinct for determination;<sup>2</sup> and the discovery of indeterminate crinoid stems in the Waterberg sandstone of the Palala Plateau by Dr. Molengraaff.<sup>3</sup>

In attempting correlations we have therefore to fall back upon the least valid basis—petrographical resemblance. If this were combined with a general parallelism in the sequence of the rocks in the various areas, it could be regarded as of the more value. Often, however, we have, in the present state of our knowledge, to try to correlate widely separated exposures of rocks, with many unconformities, and consequently varying relationships. Petrographical resemblances then prove an insufficient basis for definite correlation. In dealing with several of the divergent groups of the old rocks in separate localities.

<sup>1</sup> Cohen, in Dahms, 12, p. 118.

<sup>2</sup> Griesbach, 35, p. 56.

<sup>3</sup> Molengraaff, 61, p. 65.

all we can with certainty say of them is, that they are of Pre-Karoo age.

The difficulty begins with the granites. On the south we have granite intrusive in the Malmesbury slates; on the north there is no definite evidence forthcoming, with the possible exception of the Vredefort granite mass, that the granite is intrusive in any of the rocks now exposed. The various descriptions of Namaqualand, Bushmanland, Bechuanaland, and Rhodesia, all agree with what I have myself seen in the northern, as well as in the southern and eastern, Transvaal, where the granite is the basement rock on which the other formations—in the Transvaal, Witwatersrand Series, Black Reef Series, Waterberg Sandstone, and Karroo System—rest unconformably.

Many descriptions have been given of gneisses and schists into which the granite is intrusive. The gneisses which I have seen throughout the Transvaal are banded or sheared portions of the granite; while the schists are, in some cases, aplitic or micaceous zones; in others, marginal differentiations; and, in others, sheared basic intrusions. In fact, in localities whence such rocks have been recorded, I found no gneisses and schists older than the granite, which has been supposed to have intruded into them, but the rocks so described are simply variations of the granite, due partly to magmatic differentiation, and partly to original movements during the unequal solidification of the mass, or they are foreign intrusive rocks, of later age than the granite, rendered slaty or schistose by the subsequent earth-movements that have affected the whole region. The northern granite appears to me as if it were the basal portion of some great igneous mass, which may at one time have had an intrusive relationship with some mass of stratified rock, which was older than the Witwatersrand Series but which has not yet been definitely recognised, if indeed it be discoverable, owing to the extensive denudation which it has undergone, and to the possibility that its remnants may be covered by more recent formations. That the granite is very old, and had been submerged again and again, is shown by the fact that it is overlain unconformably by beds varying in age from the early Witwatersrand Series down to the beds of the Karroo System.

The correlation of the Witwatersrand Series with any of the Cape rocks is still very uncertain. The most favoured view is that the auriferous conglomerates, with their associated slates and quartzites, are of the same age as the Table Mountain Series. The petrographical characters of the quartzites and conglomerates in the latter formation—if one could place much reliance on mere resemblances among quartzites, or even conglomerates—are in some parts of Cape Colony very like those of the beds of the Witwatersrand Series. The similar relation of the Witwatersrand Series and the Table Mountain Series to the underlying granites, might be adduced as another



argument, but that assumes the correlation of the granites, which is not at present warranted. Besides, the Black Reef—often petrographically not unlike Table Mountain Sandstone—rests unconformably on the granite, and might therefore on these same grounds have a claim to be regarded as correlative with the great quartzite group of the south.

The Table Mountain Series of the Cape is practically a quartzite series, and it contains none of the varieties of striped ferruginous slates, so characteristic of the Witwatersrand Series in the northern colonies. The persistence of such beds as the contorted Hospital Hill Slate throughout the Transvaal, and even in Rhodesia and the Orange River Colony, suggests that their absence on the south is a weakness in the correlation, which is based on petrographical similarity between the quartzites. One may, of course, say that the absence of such slates is not a sufficient basis for rejecting the correlation, but the persistence of petrographical features is one of the notable peculiarities of the South African strata, and leads one to expect a lithological resemblance throughout the two series if they are the same, while the fact that the northern strata are similar throughout their extent, and the southern throughout theirs, but each petrographically dissimilar as a series to the other, makes me prefer to regard the question as still open.

Unconformably above the Witwatersrand Beds lies what is in the main a volcanic series, with, however, numerous sediments, in the western Transvaal especially, forming part of it.<sup>1</sup> This volcanic series continues along the valley of the Vaal into northern Cape Colony, but unfortunately, where it is known in the latter Colony, we have none of the typical Cape series of the south recognisable, so that the volcanic series does not afford much assistance in the main difficulty caused by the divergent characters of the old rocks of the north and the south of Cape Colony. The recognition of the existence of such a series has, moreover, raised the question of the correctness of the identification of several supposed occurrences of Dwyka Conglomerate—notably that at Mafeking. Dr. Hatch recently visited the country near there, and found undoubted boulder beds of the same nature as those which he described associated with the volcanic series at Ventersdorp.<sup>2</sup> The rocks at Mafeking are described by Dr. S. Passarge<sup>3</sup> in a recent important contribution to our knowledge of British Bechuanaland—the only geological description of that territory which I know—and he only with apparent hesitation decides to agree with previous determinations that the conglomerate is Dwyka. His description of its association with amygdaloids points to the reasonableness of his hesitation, for after Dr. Hatch's re-

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<sup>1</sup> Hatch, 44; Corstorphine, 14.

<sup>2</sup> These observations have since been published in a paper entitled, "The Geology of the Marico District." *Trans. Geol. Soc. S. Africa*, VII., p. 1., 1904.

<sup>3</sup> Passarge, 66.

searches there is little doubt that we are not dealing here with Dwyka at all, but with a facies of the volcanic series petrographically resembling that rock.

The rocks immediately above this volcanic series, namely, the Black Reef, the Dolomite, and the Pretoria Series, form a well-marked stratigraphical group, passing conformably upwards, but showing a marked break at the base of the Black Reef Series, which sometimes rests directly upon the old granite. To this group the term Cape System has latterly been restricted, but it would be much better were this name left out of Transvaal geological nomenclature entirely, as it assumes a correlation for which little basis exists. Dr. Molengraaff, in his first report as State Geologist, thought the three-fold division a good reason for suggesting a parallelism with the Table Mountain, Bokkeveld, and Witteberg Series;<sup>1</sup> but in 1899, after we had made a joint tour in the Cape Colony and the Transvaal, we concluded that the most one could say was, that probably as a whole the Black Reef, the Dolomite, and the Pretoria Series corresponded to the Cape System of the south, but that the correlation in detail was not warranted. This conclusion was published by Dr. Molengraaff in a letter to the editors of the *Neues Jahrbuch* in 1900.<sup>2</sup>

The difficulty, of course, lies in accepting a mere broad petrographical division into three series, as equivalent to the distinctness which the fossiliferous Bokkeveld Beds give to the three-fold division of the Cape System, in the southern colony. On the other hand, if Cohen's determination of the fossils, which he found in the dolomite of the western Transvaal, can be supported by further finds of distinctive species, there may be some reason for considering the dolomite as being more or less of the same age as the Bokkeveld Series.

We need have no hesitation in accepting the Transvaal dolomite as on the same horizon as that of the Campbell Rand, for the continuity has been practically proven. This forces us to regard the Keis Series and the Black Reef as equivalent, and the Griquatown and the Pretoria Series as the same. The unconformable relationship of the Keis and Black Reef Series to the granite, and the petrographical resemblances of the Griquatown and Pretoria Series are additional facts supporting this view. Unfortunately this brings us no nearer to the discovery of the relationship of these strata with the beds of southern Cape Colony, for, as I have pointed out, none of the typical southern rocks are known on the north.

The Plutonic Series of the Bushveld may have representatives in some of the igneous rocks on the north of Cape Colony, which so far have been only partially described. The Waterberg Sandstone, now known to be unconformable to the Pretoria Beds, probably finds its parallel in

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<sup>1</sup> Molengraaff, 58.

<sup>2</sup> Molengraaff, 60.

Stow's Matsap Series of Griqualand West. When Dr. Molengraaff, in his 1898 report, described the two foregoing as distinctive series, he thought they might be regarded as two new members of the Cape System (see p. 168) not hitherto recognised, and perhaps not existing in the Cape Colony, a view retained in his French paper. If, however, there is ground, from their relative positions to the underlying series, for assuming the correlation of the Waterberg Sandstone and the Matsap Series, there is no reason to regard either of these as occupying a position intermediate to the Witteberg and Ecca Series of the Cape. It is true that in the Transvaal the Dwyka conglomerate is the formation next in age to the Waterberg Series, but the unconformity beneath the Dwyka on the north is so great that we cannot infer that the youngest rocks found underneath it there, should be correlated with those conformably below it on the south of Cape Colony.

The differences which exist between the rocks of the northern and southern portions of the region considered in this paper, point distinctly to a different geological history for north and south. It is certain that the northern area was a land surface, at different intervals, while the southern was under the sea, and it may therefore be impossible, owing to the absence of fossils and the presence of many gaps in the series, to correlate with accuracy the rocks in question. Penning was not far wrong when, in 1891, he said the only northern formation which could be classified—though his classification was incorrect—was the coal formation. Definite correlation with the Cape rocks first became possible when it was discovered by Bergrath Schmeisser,<sup>1</sup> in 1893, that the fossil plants in the Transvaal coal measures correspond to those of the Ecca Beds of the Cape—a discovery amply confirmed by the comprehensive work of Seward on the South African fossil floras, as well as by that of Zeiller,<sup>2</sup>—and that, therefore, the breccia, which had been mentioned by Sawyer and others as occurring at the base of the coal formation, corresponds to the Dwyka Conglomerate of the south.<sup>3</sup> This was an important stratigraphical advance, and it gave a unity formerly lacking in South African geology. Further confirmation of Schmeisser's important correlation was made in 1897 by Dr. Molengraaff's discovery of unmistakable evidence, in the Vryheid district, that the Transvaal Dwyka Conglomerate is a true ground-moraine, lying at the base of the Ecca shales.

Transvaal geology—except for superficial deposits—ends with the Ecca Series, which Mr. Seward's determination of the Vereeniging and Cape plants<sup>4</sup> now enables us to regard as

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<sup>1</sup> Schmeisser, 84, p. 67.

<sup>2</sup> Zeiller, 108.

<sup>3</sup> For a complete discussion of this important correlation see the Ann. Rep. Geol. Com. for 1899, or The Scot. Geogr. Mag., Vol. XVII., p. 57.

<sup>4</sup> Seward, 87, 88, 89.

equivalent to the late Carboniferous of other parts of the world. It is obvious, therefore, that the interior of South Africa has been a land area since the close of Palaeozoic times. The surface, as we know it, is the product of nature's denuding forces throughout a period whose determination in years would convey little to the human mind. No part of the world probably shows better illustrations of the result of long-continued denudation than does South Africa, which, if young in civilised history, is a country whose physical features are of no mean age.

The many interesting inferences as to the past physical geography of this region, to which the knowledge of its stratigraphy leads, is a fascinating problem which I cannot here enter upon, but, with the solution of the economic questions involved in stratigraphical research, its answer should be the chief outcome of our labours.

I have in conclusion to apologise to my fellow members for the many imperfections of the foregoing sketch, imperfections of which no one is more cognisant than myself, but when much of one's time is spent in travelling, it is not easy to attain the quietude essential to study, and so necessary for completeness in a review such as I have tried to give. There is besides the great difficulty—soon, however, thanks to the Seymour Memorial Library, to be removed—of obtaining in this town, or even in South Africa, the necessary serial scientific literature. The dearth of journals and periodicals makes it impossible for one writing here, to do justice to all who have tried to unravel the interesting problem of South African stratigraphy.

I hope, however, that I have said something to appeal to the many members of this Association who find their private pleasure in matters scientific. It should be stimulating to all such to know that the men who did the earliest, and, I may rightly say, some of the most valuable work in South African geology, were not distinguished professional visitors, but amateurs, in the true sense of the term. The four early workers, Bain, Atherstone, Sutherland, and Stow, whose names are familiar to all interested in South African geology, had to teach themselves, had in the main to make their own opportunities for geological investigation, and this with little encouragement from their fellow colonists, for Bain once wrote that his chief joy in the comparatively rich reward which his work brought him from home, lay in the fact that no one could say he had wasted his time, or devoted to a useless science, energies which should have been employed in the service of his family. It is no small tribute to the private worker that the groundwork of all South African geology should have been laid by one, that the unhesitating determination of the mineral to

which South Africa owes its entrance into the world of industry, should have been made by another, and that the true explanation of the origin of one of the most puzzling rocks in the world, should have been made by a third.

It must be plain to everyone that the end of the story is still far from reached, and that there is work in abundance for all of us who find pleasure in reading "Nature's infinite book of secrecy." We may hope, therefore, that, with the encouragement of the South African Association for the Advancement of Science, other Bains and Stows will arise, whose work will bring them, not the scanty sympathy and financial distress which fell to the lot of the first Stow, but a full South African measure of that generous recognition which, from across the sea, gladdened the life of Andrew Geddes Bain.

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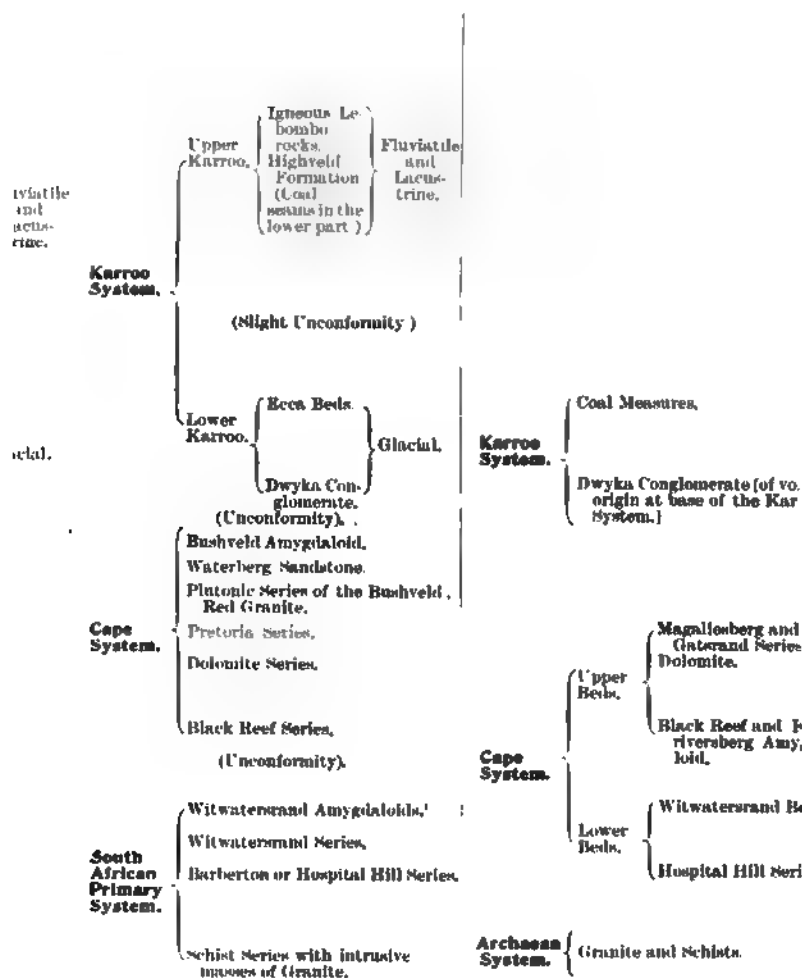
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The appended chart presents in tabular form some of the many views of the sequence of South African rocks, and, as far as possible, the correlations which have been suggested by the authors to whom I have mainly referred.

### 13.—THE GEOLOGICAL FEATURES OF THE DIAMOND PIPES OF THE PRETORIA DISTRICT.

BY HERBERT KYNASTON, B.A., F.G.S., DIRECTOR OF THE TRANSVAAL GEOLOGICAL SURVEY, AND A. L. HALL, SECOND FIELD GEOLOGIST.

(Plates VII. & VIII.)

#### INTRODUCTORY.

In the following communication we propose to give some account of the geological features of the Pretoria District diamond pipes, with a general sketch of the structure of the surrounding area. We propose to describe only those diamondiferous pipes or vents, where mining operations are at present being carried on. We shall not concern ourselves with mining matters or statistics, but shall treat the matter from a purely geological point of view.

The material of the paper is the result of work done by us in the course of our official duties on the Geological Survey during the latter part of last year. We are indebted for some of our information to the managers and other officials of the various mines visited, and we would take this opportunity of thanking these gentlemen for their courtesy and assistance.

#### AREA AND SITUATION.

The area occupied by the Diamond Fields is a somewhat difficult one to define, as our present knowledge as to the number and distribution of the pipes can hardly be said to be final. But leaving future development out of consideration, we may say that they consist of a group of diamondiferous pipes situated on the elevated ground which forms the watershed between the Pienaars and Elands rivers.

The accompanying map (see Fig. 1) shows the situation of this group of pipes, and it will be observed that they are arranged roughly in a line running nearly due north and south. The most northerly and most important of the diamond pipes is the Premier pipe, situated on the farm Elandsfontein (85), about 7 miles N. of Van der Merwe and 22 miles from Pretoria. A short distance to the west of the Premier Mine lie the alluvial workings of the Pretoria District and Beynespoort Companies. Further south, on the boundary between the farms Vryneb (74) and Rooikopjes (209), we have the recently discovered Montrose pipe, about  $2\frac{1}{2}$  miles N.E. of Van der Merwe; and passing to the south of the railway line we find the Schuller and Kaalfontein Mines, about 2 miles S.E. of Van der Merwe, and on the boundary between the farms Rietfontein (501) and Kaalfontein (402). Quite recently another pipe has been found on the farm Zonderwater (173), but this we have not yet been able to examine.

GENERAL GEOLOGICAL STRUCTURE OF THE DIAMOND FIELDS.

We will now glance briefly at the general geological structure of the area in which the diamond pipes are situated.

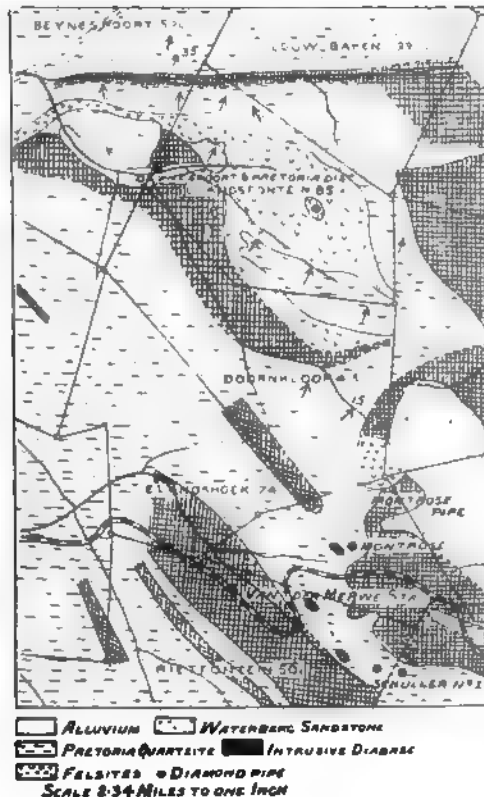


Fig 1. Sketch Map of Diamond Area.

The area represented upon the accompanying map (see Fig. 1) is mainly occupied by some of the uppermost quartzites, shales, and sheets of diabase, of the Pretoria Series. On the eastern margin of the map are seen some small patches, mainly consisting of purplish and red sandstones, belonging to the Waterberg formation. These are portions of far more extensive masses, covering considerable areas to the north and east.

By the Pretoria series is meant that formation which lies between the Dolomite and the Waterberg sandstone, and which was assigned by Dr. G. A. F. Molengraaff to one of the upper divisions of his Cape System, or rather Transvaal System, as

he has more recently proposed to call it.\* This system comprises, in ascending order, the Black Reef, the Dolomite, the Pretoria Series, and the Waterberg Sandstone. The Pretoria series is essentially a quartzite and shale series, with numerous intrusive sheets of diabase and other allied igneous rocks. In its lower portion, so far at least as the Pretoria District is concerned, shales and slaty rocks predominate over quartzites, while the upper beds are mainly composed of quartzites. The series has been well described by Dr. Molengraaff in his *Memoir on the Geology of the Transvaal*, published by the Geological Society of France in 1901.† We shall confine ourselves here to a brief description of its chief characters as seen in the diamondiferous district.

In the south-west corner of the map we have the main quartzite of the Magaliesberg range, a continuation of the same quartzite which is so well seen immediately to the north of Pretoria at Wonderboom Poort. Here, however, the quartzites, instead of striking across country in an east and west direction as they do to the north of Pretoria, have been bent round by earth movements, so that they have assumed a general north-west and south-east trend. This change of trend commences on the east side of Franspoort, a few miles beyond the west margin of the map, and at Pienaarspoort plenty of evidence of movement may be seen, the beds being considerably disturbed and traversed by small faults, causing repetition of outcrop, change of dip, etc. There is no doubt that the movements affecting the Pretoria series were accompanied by considerable faulting. The actual lines of dislocation, however, are difficult to pick out, owing to the uniform character of the beds over considerable areas, and the frequent occurrence of superficial deposits concealing the behaviour of the rocks beneath. In the case, however, of comparatively thin beds of quartzite cropping out in areas of shale, the faulting, of course, is much more easily detected, and beautiful examples associated with the movements above referred to may be seen traversing the lower quartzite zones of the Pretoria series to the east and south-east of Pretoria.

But to return to the particular area we are dealing with. Leaving the Magaliesberg quartzite, we pass in a general north-easterly direction across a succession of quartzites and intrusive sheets of diabase, and this is here the principal characteristic of the uppermost portion of the Pretoria series. Beds of shale occasionally occur, but in this area they are insignificant in comparison with the quartzites. We find dark grey and black shales, for instance, well exposed in the spruit

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\* See Ann. Rep. Geol. Survey, S.A.R., 1898, p. 3 (English translation). Explanatory Note to Geol. Sketch Map of the Transvaal, 1902, pp. 5—9; Also, Molengraaff's Address to Geol. Soc. Trans. S.A. Geol. Soc., Vol. 5, Pt. 4, p. 74.

† See *Géologie de la République Sud-Africaine du Transvaal*, Bull. Soc. Géol. France, 4<sup>e</sup> Série, Tome, 1, Paris, 1901, p. 41.

below the Schuller and Kaalfontein Diamond Mines, and again similar shales may be seen a few miles to the north of the Premier Mine, on the farm Louwsbaken (399). These shales closely resemble the more extensive argillaceous deposits of lower horizons in this series.

The quartzites are mostly fine-grained rocks of a pale yellowish, or sometimes white colour. A purplish tinge is often noticeable, especially over parts of the area near the northern margin of the map. The texture may vary considerably, somewhat coarse-grained saccharoidal types occasionally occurring. These rocks as a rule show well-marked dip-slopes, and ripple-marked surfaces are a characteristic feature. Banded quartzites showing parallel laminae, rich in oxide of iron, are sometimes found not far from the northern slopes of the Magaliesberg range.

We will not describe the Waterberg rocks, which are seen on the east margin and in the north-east corner of the map; we will merely point out that these beds have been shown, by the recent work of Mr. E. T. Mellor, further east, to be lying unconformably upon the Pretoria series. In this region, however, the unconformity cannot be clearly seen, as both series show approximately the same degree and direction of dip, and both consist, along the line of junction, of somewhat similar types of quartzite and quartzitic sandstone.

As regards the igneous rocks seen upon the map, these may be classed, with certain exceptions, under the general and convenient term of diabase, though probably several varieties of altered dolerites and diorites may be found among them. They form intrusive sheets or sills in the Pretoria series.

A specially interesting point in connection with one of these intrusive sheets is the intimate association, in what is apparently a single intrusion, of diabase and felsite. This sheet may be followed along a well-marked ridge on the farm Beynespoort (520), till it spreads out further east to form the group of hills surrounding the Premier pipe. Thence it is continued through the farm Doornkloof (431) to the summit of some high ground at the south-east beacon of the same farm. The same sheet has been picked up again further east and traced as far as Bronkhorst Spruit. The lower portion of this sheet is usually a fairly coarse or medium-grained diabase of the normal type. Now, this diabase is frequently found to be overlain by a compact reddish or flesh-coloured, and sometimes greenish, felsite, and it is impossible to find any sharp line of demarcation between the two rocks. The diabase becomes gradually more and more fine-grained, and more and more acid, owing to the loss of its ferro-magnesian constituents. The holocrystalline granular structure of the diabase gradually gives place to a compact felsitic structure, with frequently spherulitic aggregations. In the intermediate phase of the



passage one often finds a reddish rock resembling rather a syenite or diorite than the more basic diabase.

It would appear, therefore, that in this intrusion there has been magmatic differentiation, which has taken place, so to speak, in a vertical manner, the more basic portion of the magma having concentrated in the lowermost portion of the sheet and consolidated as diabase, while the more acid portion has remained to constitute the felsite of the upper part.

#### THE PREMIER PIPE.

We will now consider more particularly the geological features of the celebrated Premier Diamond Pipe. This pipe is situated about 7 miles north of Van der Merwe, on the northern portion of the farm Elandsfontein (85). It has an elevated situation, compared with the general level of the surrounding country, and lies in a basin-shaped hollow, surrounded by ridges and kopjes of felsite. At the north-west end of this hollow there is a break in the felsite hills, through which a small stream finds exit to the lower ground, and the alluvium associated with this stream is worked for diamonds, by the Pretoria District and Beynespoort Companies.

At the surface the pipe is an irregular oval in shape, the longer diameter of which measures just over half a mile. The area of diamondiferous ground at the surface was calculated by the Diamond Mines Commission in November last to be 350,000 square yards (equal to 3,280 claims). The Premier Pipe is, therefore, the largest known diamondiferous vent in the world.

As already pointed out, it is almost entirely surrounded by felsitic rocks, which form the upper portion of an extensive intrusive sheet. A small patch of quartzite, however, is seen cropping out on the northern edge of the pipe. There is no reason, however, to suppose that the felsite has any connection whatever with the volcanic forces to which the pipe owes its origin. It was undoubtedly intruded into the Pretoria beds at a time far anterior to the formation of the pipe, which has, at a much later date, been pierced through the felsite and the quartzites which underlie it. Thus, the walls of the pipe, where they are exposed in the present open workings (No. 1), are composed of this felsite. At greater depths, however, the walls would in all probability be found to be composed of the quartzites, which the structure of the surrounding country shows to underlie the felsite.

As regards the internal structure and arrangements of the pipe a certain amount of information may, of course, be derived from the open workings of the mine, and from the boreholes, which have been put down by the Premier Company; but naturally, until larger areas and greater depths of the mine have been opened out, our information upon various points of interest is bound to remain somewhat obscure.

## BORE-HOLES.

At the time of our last visit to the mine, eight bore-holes had been put down to depths varying from 300 to 1,001 feet. The ground passed through is on the whole similar in its nature and appearance in the various bore-holes, and consists of:—

1. Surface soil.
2. Red ground, often mixed with sand, gravel, and boulders.
3. Yellow ground.
4. Blue ground.

The level of the blue ground varies in different parts of the pipe. In No. 1 open workings, which are in the south-east corner of the pipe, it is seen within 15 feet of the surface, but generally speaking it is struck at a depth of about 35 to 40 feet. Nearly all the blue matrix is soft and weathers readily, and no hard blue, or "hardibank," has been met with, except in bore-hole No. 8, which is somewhere near the centre of the pipe. The Premier blue ground is frequently of a rather greenish colour, and with the exception of the ubiquitous "carbon" (ilmenite) does not contain such a high proportion of the minerals usually associated with the diamond, such as garnet, serpentine, chrome-diopside, mica, etc., as is found, for instance, in the blue ground of the Schuller and Kaalfontein pipes; and it may possibly be of a slightly less basic composition. The red and yellow ground near the surface invariably show a large percentage of foreign matter in the form of rolled quartzite and other fragments. That there has been a certain amount of concentration at the surface of the heavier minerals would seem very probable, as may well be the case in all diamondiferous deposits exposed to the action of denuding agencies—the lighter particles being the more readily carried away by surface waters.

On one side at least the walls of the pipe appear to extend vertically downwards, namely on the south-west side, near to which a bore-hole (No. 1) has gone down for 1,001 feet in uninterrupted blue ground—though this does not exclude the possibility of an outward bulge in the wall.

Small bands of quartzite are sometimes met with in the bore-holes in the solid blue, but these very probably represent portions detached from the surrounding walls. Thus, in a bore-hole (No. 8) put down near the centre of the pipe, about 11 feet of hard pale quartzite were passed through at a depth of about 500 feet. This was succeeded by hard, dark greenish-blue ground, resembling the "Hardibank" of the Schuller Mine. At a depth of 760 feet a fine-grained black igneous rock (resembling a lamprophyre) was met with, and about 70 feet of this rock had been passed through when news of this bore-hole was to hand in February last. The rock may very possibly represent an intrusive mass, perhaps a dyke, cutting the blue ground.

In this connection it will be of interest to refer to the occurrence within the pipe of what is termed "floating reef." A considerable quantity of this is met with in No. 1 open workings. It does not appear to extend to any depth, however, being so far, on an average, about 20 feet in thickness, and the bulk of it will probably be removed before very long. It consists of a bar of hard purple quartzite and indurated grit, associated in places with purple conglomerate and breccia. It is well exposed along the north side of the workings. A mass of conglomerate is also well seen on the opposite side of the workings close to the lower end of the inclined railway. These rocks have evidently been much indurated by volcanic action, yet they bear a very remarkable resemblance to rocks belonging to the Waterberg series, which, as we have seen, succeed the uppermost Pretoria quartzites, and are found *in situ* a few miles to the north and east of the pipe. Moreover, no rocks of exactly this type have been as yet met with among the Pretoria quartzites. It would not be unreasonable, therefore, to conclude that the Pretoria beds, which at present surround the pipe, were at one time covered by conglomerates and sandstones of Waterberg age, and that the masses of these latter rocks, now found enclosed in the diamondiferous ground, represent portions which had been broken away from the sides of the old volcanic crater, which stood over the site of the present pipe, and in this way have become buried in the volcanic matter within it. Since that time, the volcanic crater and the surrounding Waterberg rocks have been swept away by denudation, so that to-day we see the pipe or vent, which fed this ancient volcano, surrounded by the underlying Pretoria quartzites and intrusive igneous rocks.

A precisely similar instance to the above was noticed not so very long ago in the case of a large volcanic vent of Tertiary age in the island of Arran, off the west coast of Scotland.<sup>1</sup> Here, large masses of Rhaetic and Liassic strata, containing characteristic fossils, and blocks of Cretaceous rocks, were observed embedded in the agglomerate within the vent. The mass of Rhaetic rocks was several acres in extent. Similar rocks of the same age are now only found *in situ* in that district in the south of Arran, so that the occurrence of the included masses in the vent not only indicates the former much wider spread of these rocks, but also that they must have fallen down into the vent from the old crater walls in order to have acquired their present position. Other instances have also been observed in the Palaeozoic strata in some of the Scottish Carboniferous vents.

Apart from the Premier Mine, which at the present time contributes by far the greater portion of the Diamond output

<sup>1</sup> See Q.J.G.S. Vol. LVII. 1901, pp. 226-229. Murray, Powell and Gairn.  
 "On a remarkable vent of Tertiary age in the Island of Arran, containing Mesozoic fossiliferous rocks."

of the Colony, we find the following Mines at work :—

- |                               |   |
|-------------------------------|---|
| 1. The Schuller Mine          | } Blue ground occurs as a true pipe.          |
| 2. The Kaalfontein Mine       |   |
| 3. The Montrose Mine          |   |
| 4. The Pretoria District Mine | } No pipes have been found in these workings. |
| 5. The Beynespoort Mine       |   |
| 6. The Montrose Alluvial Mine |   |

Though economically considered, the above mines are less important than the Premier Mine, they are nevertheless extremely interesting to the geologist, as they present certain features which throw some light on the origin of the Blue ground.

The Diamond-bearing ground may occur either as solid rock *in situ* in the form of pipes, or else as an alluvial deposit, and the classification of diamond-bearing localities on this principle is indicated above; in the following remarks we will confine ourselves to the occurrences of pipes only.

#### THE SCHULLER, KAALFONTEIN, AND MONTROSE PIPES.

The mines which show true pipes occur at a distance of a few miles to the S.E. and N.E. of Van der Merwe Station, some 22 miles east of Pretoria. (See Fig. 1.)

The Schuller No. 1 Mine has been worked the longest, as Diamonds were obtained from this source already before the war.

Its occurrence was briefly noticed by Dr. Molengraaff in his first Report as State Geologist under the old Government.\* The Mine lies about 2 miles S.E. of Van der Merwe Station, on a gentle slope, over which the beds lying above the Magaliesberg Quartzite of the Pretoria Series crop out. These sedimentary rocks consist of whitish thickly-bedded quartzite, dipping to the north-east at an average angle of 18 deg. The pipe appears through these beds in the form of an irregular oval at the surface, the longest diameter of which is 240 feet, while the breadth is about 200 feet. Its contact with the white quartzite is in several places clearly visible and rather sharp. Thus at the north-east corner of the pipe one can notice a shallow pit about 5 feet deep, the northern wall of which represents the contact plane between the blue ground and the sedimentary rocks. The latter consist of whitish to grey quartzite, showing a somewhat smoothened and slickensided aspect. Again, on the opposite south-east corner, there exists a hauling adit, the sides of which attain a maximum height of about 12 feet. This adit runs approximately across the strike of the quartzite, and displays a regular dip of from 16 to 18 degrees, but as one approaches the mine, evidence of an increased amount of jointing can be seen, until, within two or three feet of the contact, the sedimentary rocks appear

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\* First Annual Report of the State Geologist for 1897, Johannesburg, 1898, Trans. S.A. Geol. Soc., Vol. IV.

much broken and disturbed. The boundary line between the blue ground and the quartzite is sharp enough to be easily covered by the hand.

It thus appears that the blue ground occupies its present position through the agency of an eruptive force, which has broken through the upper quartzite beds of the Pretoria series, resulting in the formation of a more or less cylindrical and vertical mass or "pipe."

The hard blue ground contains a number of foreign fragments, included in the parent rock by the disruptive action of the volcanic forces on the surrounding rocks. These rock fragments chiefly include Quartzite, Shale, and pieces of Igneous rock, e.g., Diabase.

In the Schuller No. 1 pipe one finds a thin covering of soft yellow material, the so-called "Yellow ground." This represents the product of the highly-weathered hard blue ground, and forms a most valuable asset to the miner, on account of its being very easily broken up and washed. Indeed, the fresh blue ground of this mine, containing much of the so-called "Hardibank" of the Kimberley type, was soon found to be unmanageable, and quite intractable to the ordinary method of weathering. For this reason the pipe No. 1 is now no longer worked, a result which is not due, therefore, to the absence of diamond-bearing ground, but to the hardness of the blue ground, the continued treatment of which would unduly raise the working costs. As a matter of fact, one borehole in the mine has traversed nearly 300 feet of mine ground without any sign of a termination having been reached.

Some time after the discovery of No. 1 pipe, a second occurrence of blue ground was found some 500 yards S.E. of No. 1. This turned out to be another pipe, partly situated on the farm Rietfontein—such portion belonging to the Schuller Company and known as No. 2—partly on the adjoining farm, Kaalfontein, such portion being owned by the Kaalfontein Company. An examination of this pipe shows a mode of occurrence analogous to the one already described. Here again, the pipe shows an oval form at the surface, some 400 feet in greatest length and of a maximum width of 290 feet. Of this ground the Schuller Company own some 300 feet of the eastern portion. On the surface there is a layer of about 26 feet of yellow ground, underneath which comes hard blue ground; one bore-hole, sunk into this pipe, proved the blue ground to a depth of 560 feet. The wall of this pipe is like that of the Schuller No. 1, well marked off from the quartzite surrounding it, but on the Kaalfontein side it is not vertical, but has an outward slope or bulge; sometimes the contact plane is smooth and slickensided, sometimes a distinct upward trend of the strata can be seen—especially on the walls of an inclined shaft sunk into the blue ground from the surface on

the western edge. The character and arrangement of the quartzites is similar to that already alluded to in connection with the previous mine. (See Fig. 2.)

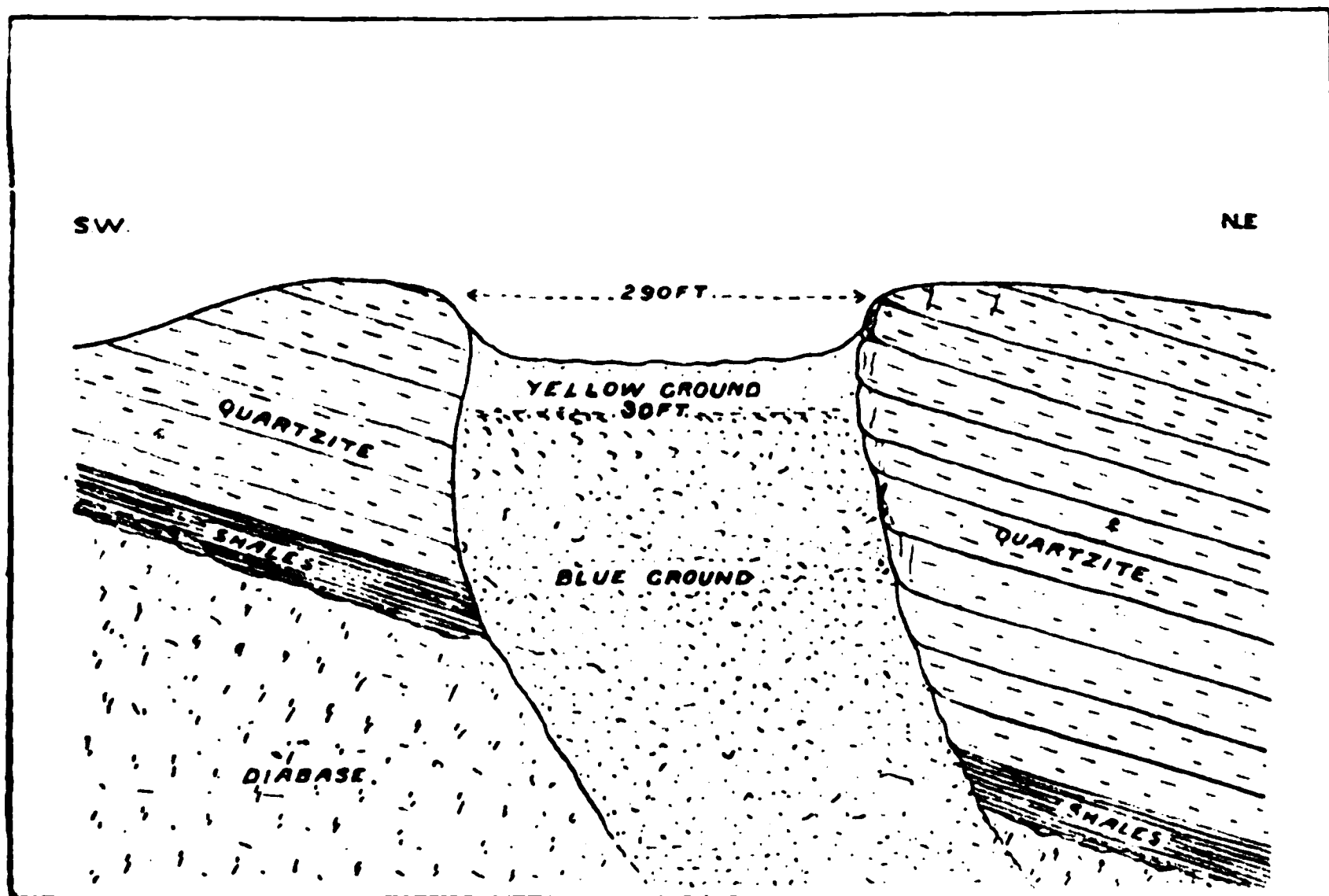


Fig. 2. Vertical Section through Kaalfontein Pipe.

Thus in both the Schuller and Kaalfontein Mines the pipe matter apparently breaks through the quartzites owing to a disruptive force from below, the effects of which on the sedimentary strata are seen in its disturbed character and in the upward curvature of the bedding planes near the contact, and in the large number of included fragments.

Another diamond-bearing pipe has been found a few months ago by the Montrose Company. Nearly the whole of this rather small pipe lies on their farm Vryneb, but a small portion of it at the N.W. end extends into the adjoining farm, Rooi Koppies. The ground is hardly yet opened up sufficiently to enable one to say what is the exact extent of the pipe or what are its relations to the country rock. It seems, however, that the latter is largely made up of an intrusive igneous rock, resembling diabase. To the north of the pipe, this diabase apparently passes into a reddish, more fine-grained rock, which may provisionally be termed felsite. On the south very little rock *in situ* occurs, only a rich red soil being seen. In a few prospecting pits lying here, rather thin bedded red shales, presumably of the Pretoria Series, can be seen, overlain by a thick deposit of red soil carrying some diabase boulders. As the work of opening out the Mine proceeds, no doubt more

definite indications will be found, which may throw some light on the behaviour of this pipe, which appears to differ in some respects from those above described.

#### NATURE OF THE BLUE GROUND.

For a study of the nature of the Diamond-bearing rock the pipes of the Schuller and Kaalfontein Mines form excellent opportunities. The blue ground occurs as a dark bluish to green rock, which breaks fairly easily under the hammer, and has a somewhat speckled appearance owing to the frequent presence of whitish foreign fragments. Here and there one meets with portions much harder than the rest, and the term "Hardibank" has been applied to this variety. Occasionally there is a tendency to assume a spheroidal form, such spheroids being identical in composition with the main mass, and attaining a size of two or more inches in diameter. It seems probable that they are merely a peculiar result of weathering.

The rock is rather light; the specific gravity taken from three samples gave the following results:—

$$\begin{array}{r} 2.791 \\ 2.748 \\ 2.733 \end{array} \left. \vphantom{\begin{array}{r} 2.791 \\ 2.748 \\ 2.733 \end{array}} \right\} \text{Mean } 2.757$$

To ensure reliable values rather large pieces were chosen for determination, such pieces also containing fragments of foreign inclusions. It will be noticed that the values found are somewhat low for an igneous rock rich in iron ores and ferro-magnesian silicates, such as the blue ground represents. It must be borne in mind, however, that the admixture of foreign fragments of smaller specific gravity, together with the metasomatic changes resulting in the production of hydrated minerals, would both tend to lower the specific gravity, which indeed agrees pretty closely with that usually met with in a highly serpentinitised peridotite. Thus the Kimberley blue has an average sp. gr. 2.734. The mean value for 13 typical peridotites (e.g., Amphibol peridotite, Diorite, Harzburgite, etc.)\* works out to 3.180, but where such rocks are highly serpentinitised, the values have been found to drop to 2.710. It appears, therefore, that the somewhat low value for the blue ground is largely due to the large development of secondary serpentine.

In the rather compact green matrix of the blue ground the following minerals can be detected with the naked eye:—

Serpentine.

Vaalite (a Magnesian Mica).

Garnet.

Ilmenite.

Chrome diopside.

Hypersthene, Calcite, and foreign fragments.

Of these the first mineral is by far the commonest: in fact, it

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\* Rosenbusch, *Elemente der Gesteinslehre*, Stuttgart, 1901.



constitutes the bulk of the matrix. Another very frequent mineral is Ilmenite (known to the miner as "carbon"), characterised by its high lustre and somewhat carbonaceous appearance. The dark brown mica is of a magnesia variety, to which the name Vaalite has been given. Chrome diopside and garnet are only sparingly present—the former showing up well through its bright green colour, accompanied by good cleavage.

Eight sections were cut from separate samples of the hardibank of the Schuller No. 1 pipe. A microscopic examination of these shows us a rock which must at one time have been very largely made up of Olivine, of which some unaltered traces are still to be occasionally seen. The matrix shows excellent mesh-structure with concomitant deposition of iron-ore along the irregular cracks of the parent mineral, olivine. A noteworthy point is the occasional extensive presence of rather fresh calcite. A close examination of the included fragments affords some indication as to their original nature, which resembles sometimes that of a diabase. The fact that Augite is practically confined to the included fragments is interesting in this connection.

The following table shows the composition of the blue ground as revealed by a microscopic study. A small circle indicates the presence of the particular mineral in the matrix, a small cross indicates its presence as a constituent of some foreign fragments:—

<i>Mineral.</i>	15a.	15b.	15c.	15d.	190.	191.	192.	193.
Serpentine	o	o	o	o	o	o	o	o
Olivine	x	x	o		o			
Bastite			o	o		o	o	
Ilmenite	o	o	o	o	o	o	o	o
Vaalite		o	o	o		o	o	
Garnet		o	o				o	o
Augite	x	x		x	x			
Hypersthene						x		
Apatite		x				x		
Calcite		x	x	x		x	o	x

Among the included fragments are found chiefly—

Quartzite,  
Diabase,  
Shale,

together with some others of doubtful nature. They vary much in size, pieces up to 3 inches in length are not uncommon, but usually they are smaller, and generally rather angular. A noteworthy feature is the occasional occurrence of calcite, apparently very fresh. The general mode of occurrence of these inclusions leaves little doubt that they are due to the breaking through of the diamondiferous rock, which caught up fragments of sedimentary and igneous rocks in its passage upwards.



A chemical analysis of the Blue ground in the Schuller No. 1 Mine gave the result shown in the following table under I. For comparison the chemical composition of Kimberley Blue is given under II., and that of the type occurrence of Harzburgite under III.

	I.	II.	III.
SiO <sub>2</sub>	33.84	33.00	35.67
TiO <sub>2</sub>	.434		
Al <sub>2</sub> O <sub>3</sub>	6.16	12.00	2.98
C <sub>2</sub> O <sub>3</sub>	.04		.87
Fe <sub>2</sub> O <sub>3</sub>	27.40		6.04
Fe <sub>3</sub> O <sub>4</sub>	.19		4.95
MgO	21.62	32.38	35.03
CaO	—	9.60	.18
Na <sub>2</sub> O	.20	.67	.77
K <sub>2</sub> O			
CO <sub>2</sub>	—	7.05	P <sub>2</sub> O <sub>5</sub> .03
H <sub>2</sub> O hygroscopic	1.23		
H <sub>2</sub> O, &c. ignition	9.33	6.00	12.04
	100.444	100.70	99.93
Sp. Gr.	2.757	2.734	2.71

I. Blue Ground Schuller No. 1. Analysis by C. Gardthausen.

II. Kimberley Blue. Rosenbusch. Elemente der Gesteinslehre Stuttgart 1901. 2nd Edition, p. 169.

III. Harzburgite serpentinitised. Radauberg nr Harzburg. Dto.

A comparison of these results shows a strong general similarity of the chemical natures of the 3 rocks. A notable feature of difference is the absence of lime in the Schuller type. There is no doubt, however, of the frequent presence of Calcite in the rock, but a reference to the mineralogical composition as revealed by microscopic study shows that the mineral in question was in all cases except one present in a foreign fragment only. The sample chosen for analysis thus happened to be free from calcareous inclusions. The amount of iron is also somewhat high, and in the ferric iron has also been included ferrous, but it was possible to estimate separately the small percentage of magnetic iron.

Apart from the minor differences, there is a fairly close analogy between the Blue Ground in question and the other rocks adduced for comparison. All three are marked by a low amount of silica, a very high percentage of magnesia, and a rather low amount of alumina. In all cases water is present in rather high amounts, a feature no doubt due to the large preponderance of serpentine, this hydrated silicate of magnesia being present in all three rocks.

## GENERAL CONSIDERATIONS AND CONCLUSIONS.

We will now briefly conclude with a few general remarks. It might perhaps be asked—Why should these diamond pipes occur in the particular area where they happen to be found? Is there any geological reason why they should occur there rather than in any other locality, or is their occurrence purely accidental? Now, as we have already pointed out, the whole of the Pretoria series in this area has been considerably affected by certain crust movements, the effect of which has been to bend the strata round in a south-easterly direction. This movement has been accompanied by oblique dislocations of the strata, which have naturally been greatest about the point where this bending back of the sedimentary series has taken place. And this change of strike, as we have already seen, commenced suddenly quite close to our Diamond fields.

Now the connection between volcanic vents and lines of weakness in the earth's crust, caused by earth-movement and dislocations of the strata, is well established. There may be good reason, therefore, for supposing that such lines of weakness have been set up in this particular area, and that thus these weak points have been finally taken advantage of by the volcanic forces which were eventually the direct cause of the production of the diamond-pipes. We are much more likely, then, to find diamondiferous vents and volcanic phenomena of all kinds in areas of disturbance and crust-movement, rather than in those areas which have undergone no particular movements at all.

As regards the age of the Diamond pipes, they no doubt all belong to the same geological period, and they are evidently younger than the Pretoria Series, into which they have been intruded. In the case of the Premier pipe, the masses of included Waterberg rocks show that this pipe is of later date than the Waterberg period, but beyond this we have no direct evidence to guide us any further. If, however, we may correlate the Transvaal pipes with those of Kimberley, then we have some further evidence to go upon as regards their age, these latter having been intruded into shales of Karroo age.

Finally, as regards the blue ground, we have shown that it is a volcanic rock closely resembling a highly serpentinised peridotite-breccia, recalling in some respects the characters of Kimberley blue, and containing fragments of other rocks, both igneous and sedimentary, derived from the breaking up of the strata, through which the blue ground has forced a passage.

The study of these diamond pipes is of intense interest from many points of view, but, like the Premier Mine, it is only as yet in its infancy, and we do not profess to have treated the matter here otherwise than in a very superficial manner. We hope, however, that further observations and the discovery of a few more Premier Mines will give us the opportunity of making some further communication on the same subject.

## EXPLANATION OF PLATES.

Microphot. by A. L. H.

## PLATE VII.

FIG. 1.—Section of Blue Ground from the Schuller No. 1 pipe, magnified 15 diameters (slide 193). The figure shows the general clastic character of the rock. The matrix is made up of secondary serpentine and iron ore. The large light individuals are bastite. The large dark oval shaped crystal, nearer the edge is ilmenite with a central fragment of olivine.

FIG. 2.—Section of Blue Ground from the Schuller No. 1 pipe, magnified 15 diameters (slide 191). In the matrix of serpentine are seen large light bastite pseudomorphs and a fragment of much twisted vaalite (biotite). Across the section is seen the edge of a foreign inclusion of (dark) diabase.

## PLATE VIII.

FIG. 1.—Section of Blue Ground from the Schuller No. 1 pipe, magnified 25 diameters (slide 190). The slide shows the matrix of secondary serpentine accompanied by deposition of grains of iron ore arranged along the edges of the crystals. On one side is an opaque foreign fragment enclosing some of the matrix.

FIG. 2.—Same as Fig. 1, magnified 15 diameters. The main portion of this figure shows a dark inclusion of diabase, the remainder being made up of serpentine matrix. Near the centre of the dividing line traces of idiomorphic cloudy plagioclase can be seen, while near the outer edge of the diabase occur large individuals of augite.

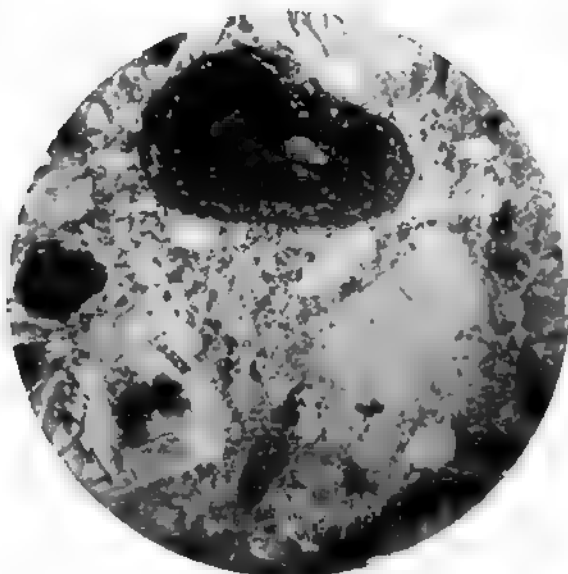


Fig. 1.

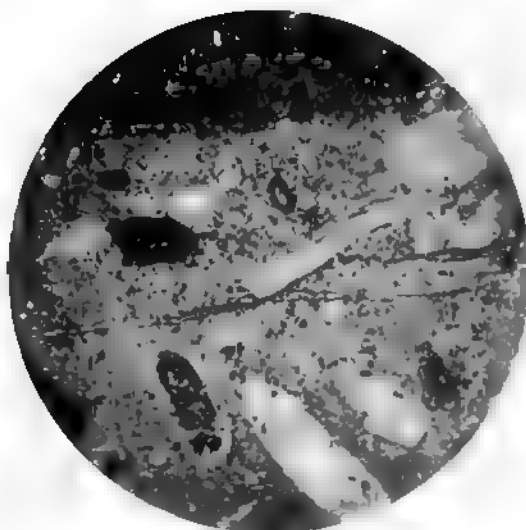


Fig. 2.

*Kynaston & Hall: Pretoria Diamond Pipes.*



14.—STONE IMPLEMENTS FROM THE FARM ELANDS-  
FONTEIN, NO. 235, NEAR JOHANNESBURG;

WITH A LIST OF PAPERS RELATING TO THE  
ANTHROPOLOGY OF PREHISTORIC SOUTH AFRICA.

BY J. P. JOHNSON.

In the latter part of 1903, I recorded, in a paper read before the Geological Society of South Africa, some discoveries of stone implements, which I had made in the neighbourhood of Johannesburg.<sup>1</sup>

They comprised—

- (1) A group presenting the complete facies of the Eolithic implements of Southern Britain;
- (2) Another group, equally identical with the true Palaeolithic implements;
- (3) A series of minute and neatly made implements, comparable to the pigmy flint implements, which characterise the Neolithic period of Europe and elsewhere.

The types of Eolithic and Palaeolithic implements particularly referred to in that paper were illustrated by drawings, which I had made on a previous occasion, of European specimens in my collection; but I had not time then to make drawings of the pigmy implements.

The object of the present note is to fill this gap, for, as all students of anthropology know, it is impossible to give a satisfactory idea of any stone implement by description alone, and figures are all the more necessary in this case, because these small implements do not appear to have been previously recorded from South Africa.

On Fig. 1, p. 200, are shown 19 of these minute implements (which come from the farm Elandsfontein No. 235), and four similar implements of nearly ordinary dimensions, all drawn to the actual size. I have included the comparatively large specimens, which are good representatives of the common scraper, for comparison with the small ones, which I now think are also scrapers. The delicacy of workmanship displayed by these examples is all the more remarkable, when it is remembered that a large proportion of them are made from such refractory materials as greenstone and quartz; further research having shown the chert specimens to be in the minority.

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<sup>1</sup> Trans. Geol. Soc. So. Afr., Vol. VI., pp. 60—66, 1903.

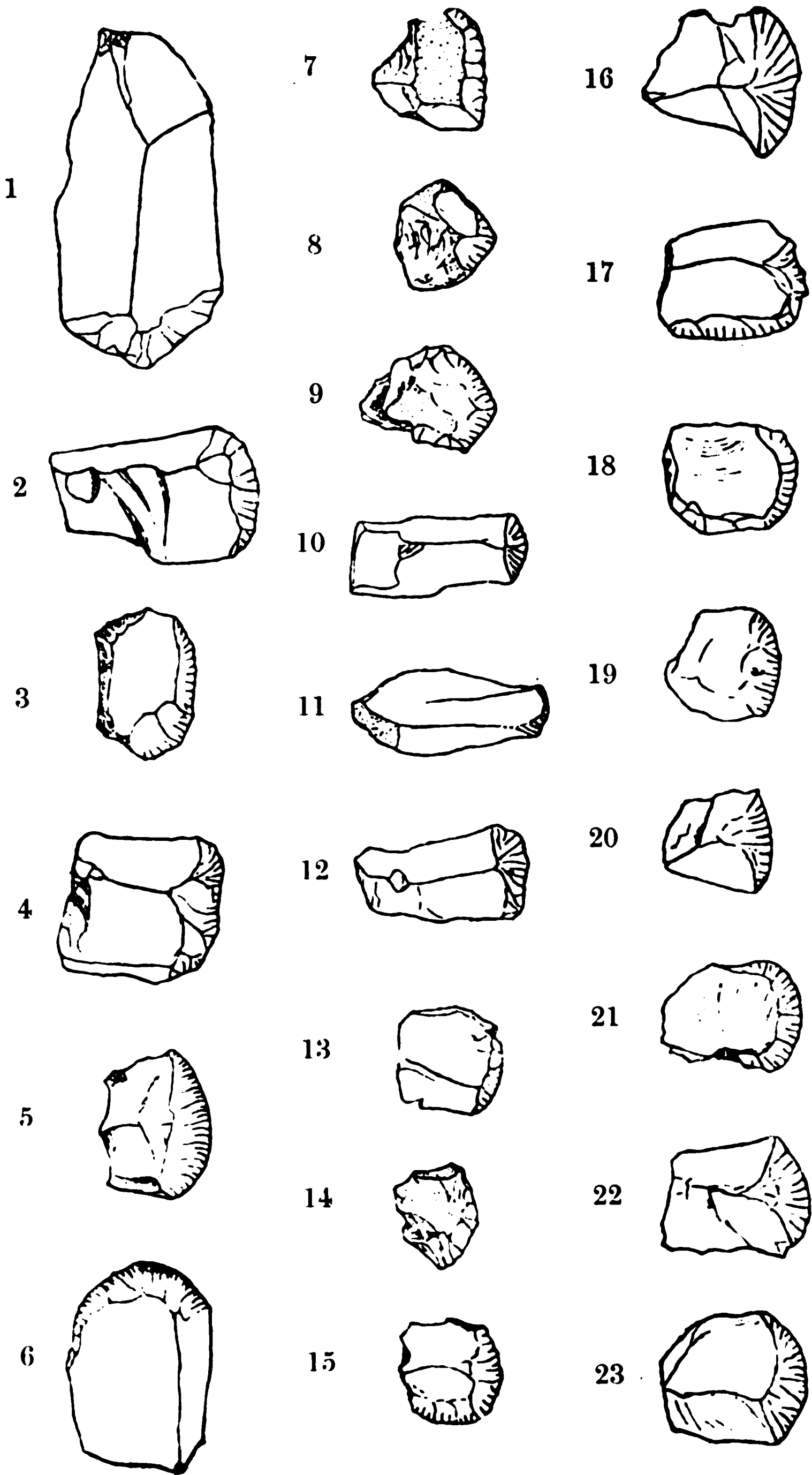
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## EXPLANATION OF FIG. 1, PAGE 200.

Twenty-three stone Implements, drawn actual size, from Elandsfontein, 235. Nos. 1, 2, 4, 10 and 13 are of greenstone; Nos. 12 and 16-23 of quartz; the rest of chert.





Stone Implements from Elandsfontein, No. 285, near Johannesburg.  
J. P. Johnson.  
Fig. 1.

## 15.—RHODESIAN TICK FEVER.

By A. THEILER, M.D., GOVERNMENT VETERINARY  
BACTERIOLOGIST.

### INTRODUCTION.

The subject I have the honour to present to you has occupied the attention of the branch of science which I have represented for over two years. Farmers, more especially those who are engaged in the breeding of cattle, and who from an economical point of view are principally concerned, should naturally be particularly interested. But as a rule they only begin to be on the alert when the disease has touched their pockets.

It is, indeed, of supreme importance for the future of the agricultural industry that this great problem should receive the careful and enlightened attention of all who have the welfare of South Africa at heart. In the first place I should be wanting in my duty were I not to state clearly that a favourable prognosis does not at present seem possible, so far, at least, as cattle-breeding is concerned.

For the past two years our Department has tried to educate the farming population to the menace which is daily threatening to ruin this industry. Notwithstanding the continued proof of the correctness of our forecast, our experience is that we have only succeeded in convincing a very small portion of the people, even of those who are chiefly concerned. The cause of this indolence and distrust is an ignorant unbelief in science generally, and in particular in that branch which my Department represents.

But the disease has not only a general economic interest, which in the future will probably occupy South African legislators more than any other stock epidemic, but it also offers a great attraction from a scientific point of view, inasmuch as research has revealed several deviations from the common type characterising the class of disease under which it has been grouped.

### NOMENCLATURE.

The disease was originally called Rhodesian Redwater, and by this name it was designated in the first government notice prohibiting the importation of cattle from Rhodesia; the name is in every respect inadequate. An improvement in the nomenclature was the words Rhodesian Tick Fever; a still better name is East Coast Fever. But since the disease is not limited to Eastern Africa, but has recently been traced to Asia Minor, in the Transcaucasian country, the name Tropical Piroplasmosis, which is used by the Russian investigators, is scientifically the most correct.

### GEOGRAPHICAL DISTRIBUTION AND HISTORY.

Tropical Piroplasmosis was first seen in German East Africa by Professor Koch in the year 1897. He then described the typical micro-organism found in this disease, but he con-

sidered them at that time to be young forms in the development of *Piroplasma bigeminum*, the cause of Texas fever, and accordingly designated the disease by that name. It was in the year 1901 that the new disease began to attract attention, south of German territories. It had broken out in a cargo of cattle intended for the re-stocking of Rhodesia, which had arrived from New South Wales.

They were detained at Beira on account of railway wash-aways and other unavoidable accidents, and while grazing on the flats at Beira the disease appeared amongst them. It must have been previous to this importation that Beira became infected, inasmuch as there were cattle grazing which did not contract the disease, and were accordingly immune.

The Australian cattle which became decimated by the disease were then brought to Umtali, in the hope that the higher veld might check the mortality.

That did, however, not happen, and finally the whole herd was carried off by the malady. Later, the native cattle around Umtali began to contract the same disease, and died. It is probable that the infection has spread from there to Salisbury and along the main road to Bulawayo and other parts of Rhodesia.

The Transvaal was invaded as early as May, 1902, when the disease was first noticed in Komatiepoort, and about the same time in Nelspruit. The new scourge had obtained a good footing before the true nature was recognised, and as Rinderpest was at that time still raging in some parts of the country the confusion of these two fatal diseases may be easily understood.

How the disease came to the Elands River Valley in the first instance is still a mystery. No connection can be traced to the outbreaks in Rhodesia. The only possible way for its importation was Delagoa Bay. But all evidence seems to indicate that Delagoa Bay became infected at a later date by cattle from the East Coast. From Komatiepoort and Nelspruit the disease spread to Swazieland, the Kaap Valley, and the Lydenburg District. The greatest portions of these districts are nearly devastated of cattle. The disease was also brought to the high veld shortly after the close of the war by farmers returning from the Elands River Valley, but in these instances although the herds were completely destroyed by the disease, the infection does not seem to have remained behind, and no other outbreaks can be traced back to these herds. The disease was brought into the district of Pretoria in November, 1902, by a herd of cattle imported from German East Africa. They landed at Delagoa Bay, where some of them died. They were then driven to Komatiepoort, where they were trucked to Machadodorp, and from there again driven to Pretoria and sold immediately on their arrival. Sick cattle and also dead ones were left behind on the road. The oxen were distributed over

a large area, mostly in the region behind the Magaliesberg and in the Rustenburg District. On these farms the disease established itself. Not only were the majority of the imported cattle already sick at the date of the sale and died shortly afterwards, but the remainder of the cattle, together with those which had been previously on the farms, began to die some weeks later of the same disease.

Some of these cattle were brought to the high veld and died there; they, however, did not seem to have left any infection behind. This apparent restriction of infection due to altitude is an interesting point, and well worthy of note. The fact is that during the last two years the disease has only spread in the low-lying parts of the Transvaal, and that the high veld is practically free of it, although the disease has at different intervals been brought to the high veld. In the course of this paper it will be shown how these facts may be interpreted.

#### MORBID CONDITIONS.

It was from the very beginning observed that the new disease was not contagious in the strict sense of the word, inasmuch as healthy cattle could mingle with diseased cattle without any danger for the time being. It was also soon noticed that certain localities had a particular influence on the mortality, and when cattle were removed out of these infected areas into clean country the disease stopped completely. Some localities are, indeed, so badly infected, that within a month healthy cattle exposed on them will be completely wiped out. Numerous observations have proved that the sooner cattle are removed out of an infected area the less the mortality. This, however, depends altogether on the degree of infection which a particular locality has undergone.

When the disease began to make its appearance in the low country along the Delagoa Bay line, and before the danger was apparent, ox wagons from Lydenburg District used to go to Nelspruit, which was probably the worst place, and still is at the present moment. Farmers went there with healthy cattle. They returned seemingly in a healthy condition, but from about seventeen days afterwards the same cattle began to sicken and died. The transport rider who only used native cattle soon realised that he was dealing with something unfamiliar to his every-day experience. A transport rider who went with his cattle into an infected locality where the disease was raging naturally lost his whole span; and although later experience taught him that the disease, although not contagious, was liable to appear several weeks later among the cattle on the particular farm where the diseased cattle had been running and dying; and although he must have recognised the abnormal symptoms quite unusual in the recent history of any of the well-known South African diseases; yet, notwithstanding these hard facts, he would not believe, nor does he still, that he has to do with a completely new disease.

The first idea, which is even now prevalent, was that the imported cattle in which the disease appeared were not accustomed to the climate of this country. This is an every-day experience, that cattle imported from England or the Continent, will die here as soon as they are exposed on pasture. Where the farmer failed to see the difference was that native cattle died off in a manner unusual for a non-contagious disease. But as usual he had his argument to explain the difficulty—an argument which will go very far with many a South African cattle breeder, and which certainly for several diseases is based on good observations—viz., the unseasonable burning of the grass. Scientifically we are able to explain many of these observations, but in this particular disease all evidence was against the popular explanation. The war was made responsible for the untimely burning of the grass. But the Boer farmer, basing his argument exclusively on local experience, will not believe that the same conditions hold good for any part of the Transvaal where the disease has not yet appeared. Notwithstanding the many arguments brought forward, we have been able to prove the real cause of the dissemination of the disease. Yet I regret that the advance which we have made has not been met with the sympathetic support of those for whom it has been primarily intended. Naturally, all legislation against the disease, which is based on scientific observations, is scouted.

#### PATHOLOGY OF THE DISEASE.

Professor Koch described the disease, as already mentioned, in the first instance as Texas fever; this is another term for our ordinary South African Redwater. When the Australian cattle began to die on the Beira flats it was found that Redwater was the cause of the mortality. There is no doubt that the first diagnosis was correct. The East Coast is just as much infected with Texas fever as it is now with East Coast fever. And Texas fever, running a shorter period of incubation and disease, necessarily showed itself first in the herd, coming from a country where there was no such disease. After the herd was removed to Umtali the mortality still continued, but now the disease was altered in type. Micro-parasites in the blood were found to be present, the same as Professor Koch had previously described as young forms of the Texas fever parasite. After a lapse of some time the new disease showed itself amongst native cattle and the cattle of transport riders, which were considered to be immune against ordinary Redwater.

The cause of this was thought to be an increased virulency of the micro-parasites, due to their passage through the highly susceptible Australian cattle. In addition to this, certain symptoms, such as haemoglobinuria, not properly understood at the time, helped to identify the disease with the already existing Texas fever.

The observation of its spreading and general behaviour, as already pointed out, indicated that the cause must be identical with that of Texas fever. Although we now distinguish between the two diseases, the fact remains that they belong to one and the same group, which are scientifically termed piroplasmosis, being due to micro-organisms investing the red corpuscles of the blood. There exists in South Africa a similar disease in horses, mules, and donkeys, and also in dogs, which is commonly called Biliary fever.

The micro-organism is called piroplasma.

The one found in Texas fever was first described under the term *Pirosoma bigeminum*, the name given by its discoverers, Smith and Kilborne, on account of the pear-shaped form, two parasites usually hanging together. These parasites are rather big, and very often reach in length the whole diameter of a red corpuscle. Another form of the same parasite is the sphericle parasite, a round disc, which is usually met with in the dead animal. This indicates that it is a later form of the pear-shaped one. When using the different modifications of Romanowsky's stain, for instance, Ginsa's Azur II., within the parasite, a deep violet-stained chromatic body is recognised, which represents the nucleus of the cell and is called karyosoma.

The cytoplasm of the parasite usually takes a bluish tinge. The karyosoma lies always on the margin of the parasite, in the pear-shaped form near the big curve. The spherical form has the aspect of a ring, not unlike the ring forms described in tropical malaria of men. The karyosoma is as a rule well defined, but chromatic substance is sometimes also met with unconnected with the nucleus, and frequently quite opposite it. The piroplasma must be regarded as belonging to the protozoa order, and may be ranged in under the haemosporidia, thus showing a certain relationship to the parasites in malaria of men and birds.

The multiplication of the piroplasma takes place in the blood, two and more individuals linked together indicating the division they had undergone; but intermediate forms are also observed, where the karyosoma flattens out, showing a groove from which the fission starts. This process of multiplication corresponds to the invasion of the blood corpuscles by the plasmodium of malaria, which is called Schizogeny, that is the asexual phase in the life cycle of the parasite.

The sexual development or Sporogeny takes place in the case of plasmodium in the body of a mosquito, and from analogy we are entitled to the hypothesis that sporogeny also takes place in the body of the intermediate host of piroplasma, that is, in this instance, the tick. I have dwelt, with purpose, somewhat extensively on the description of the parasite of Texas fever, because this is the prototype of the genus piroplasma, and because it plays a very important role, as will be shown later.

in connection with the disease under discussion. The parasite of East Coast fever, at one time considered to be the young or intermediate form in the life cycle of the *Piroplasma bigeminum*, is now regarded as a special species. It is a very small piroplasma, and differs also in shape. There are two types, the spherical and the bacillary one. The Azur stain also brings out the chromatic body and the cytoplasm. The spherical forms then have the aspect of a ring, smaller than the one mentioned before, but varying in size and shape considerably. They are either very small and round; when larger, their shape is sometimes oval or elongated. These forms are generally designated as rings. The bacillary form may be compared with a pin, which has a large head, in which the karyosome lies; the cytoplasm is drawn out into a fine line, which is either straight or curved. The criterion of the Protozoic character of these things is the typical staining of the nucleus by the method of Romanowsky or its modification.

#### PROPAGATION OF THE PIROPLASMA IN A SICK ANIMAL.

When we examine the blood of an ox infected with Coast fever whose temperature just begins to rise, we see little amiss during the first few days. When, after the lapse of about three days, the typical parasites make their appearance, they increase every day, and the longer the animal lives the greater the number of the parasites, which may become so frequent that nearly every corpuscle becomes infested. An individual corpuscle may show two or more parasites; sometimes it is quite full. Both forms, round and bacillary ones, are sometimes met with in one and the same cell. It is quite exceptional that the animal dies with only a limited number of erythrocytical infection. I have the record of such a case, where only about 10 per cent. of these cells were invaded, but more were found in the blood of different organs. Pure East Coast fever shows nothing else but the piroplasma of the small type: a certain percentage of the sick animals show in their blood also the *Piroplasma bigeminum*, and this fact was one of the reasons why the disease was first declared to be identical with Texas fever.

In a series of experiments, which had as their object to make sure that animals highly immunised against Texas fever would succumb to the new disease, thus proving the distinctness of the two diseases, we were struck to find in several highly immune oxen *Piroplasma bigeminum*. There is only one way to explain this occurrence of Texas fever parasites in immune cattle suffering from East Coast fever. The fact is that an ox which has recovered from Texas fever still carries the piroplasma in its blood in another shape. We can easily prove this by injecting blood of a recovered ox into susceptible cattle, in which case typical redwater will follow. In the case of East Coast fever mixed with Texas fever in an animal immune against the latter disease, the immunity has ceased to



exist, and a reappearance of the *Piroplasma bigeminum* under its usual aspect is the result. The same observations were repeatedly made in connection with rinderpest and other diseases, where probably the high fever and other influences lower the acquired immunity and thus favour the recrudescence of piroplasma. In the instances quoted the *Piroplasma bigeminum* appeared towards the end of the disease, that is, very long after the usual incubation time for Texas fever. In some cases, rare however, the big piroplasma is first met with, and only later bacillary forms appear. These exceptions are met with in cattle not immune against redwater, and must be interpreted as a simultaneous infection with both diseases.

#### EFFECT OF THE PIROPLASMA ON THE RED CORPUSCLES.

It will be expected that the invasion of such a number of red corpuscles as indicated above by bacillary piroplasma cannot remain without some influence.

One would naturally expect a considerable decrease of red blood cells in the first instance, but this is not the case. Records carefully made every day during the course of the disease revealed the remarkable fact that the number of erythrocytes does not suffer very much, in some instances not at all. Normally about six millions per millimeter cube, they drop in this disease to about four millions, rarely less, and not always even then, after the *Piroplasma bigeminum* has made its appearance. In a pure infection with this latter parasite the number of corpuscles may drop to one million, and even less, thus causing an acute anaemia. The disease thus naturally runs a comparatively short time, death being due to the lack of proper oxidation. There is certainly a breakdown of red corpuscles, but not sufficiently strong enough to discolour the serum of the blood or to produce haemoglobinuria, which is a natural result in the case of Texas fever. We have carefully examined many cases which were complicated with haemoglobinuria, and we have noticed that in nearly every instance where the discoloration of the urine was observed, the presence of the big piroplasma could be traced. The effect of the breaking down of a certain number of red corpuscles showed itself in the jaundiced condition of the liver, and very often of the whole system. There are typical lesions found in the disease, probably due to the unusual multitude of parasites in the different organs, and probably due to a toxic influence these parasites have on the tissue.

Experimental research has resulted in the fact that East Coast fever is not communicable by inoculation with blood taken from a sick ox, even though this blood is swarming with parasites. We have done this experiment with over thirty different animals, belonging to different breeds and of different ages. The injections were made in quantities of blood ranging from 5 c.c. up to 2 litres, either directly under the skin, in the jugular vein, or in the peritoneum. Not even a febrile re-



action could be noticed, even after several injections of blood. Certainly, some animals showed fever, but we always could trace it to some cause, either to the simultaneous incorporation of the *Piroplasma bigeminum* or the cattle trypanosoma, which were latent in the injected blood. In two instances death resulted from inoculation, but this was due to a simultaneous infection with Heartwater, as inoculation into sheep proved. All the animals injected which were later exposed to natural infection contracted the disease and died, thus indicating that the inoculation did not produce any immunity. This fact stands alone. Texas fever, the other pyrosonical disease of cattle, and piroplasmosis of the dog behave quite differently, inasmuch as blood taken from sick or recovered animals will under all circumstances produce the disease, when injected into healthy susceptible animals of the respective species. It is difficult to explain, and certainly disheartening, as the first condition for a preventive inoculation, the artificial production of the disease, is wanting.

Professor Koch has shown that the inoculation of sick blood, repeated at intervals, may be followed by the appearance of singular parasites in the injected animals. He found the same to be the case with blood from immune animals, from which he drew the conclusion that gradually immunity will be brought on. Admitting the correctness of this observation, I am induced to believe, based on my own experiments, that the symptoms are not exclusively limited to the injection of sick or recovered blood, taken from East Coast fever cases. I will revert to these points further on in this paper.

#### INCUBATION AND COURSE OF THE DISEASE.

I have already pointed out certain conditions of the appearance of the disease amongst cattle which have been exposed to natural infection and were removed out of the infection. We have seen that a certain period elapses before the animals show any visible symptoms of the malady. This time includes the incubation period. We have kept a careful record of animals exposed, and also of animals which we infected at our laboratory with ticks, and I found that this incubation time averaged about twelve days, the shortest record was ten days, and the longest twenty days. During this time nothing is amiss with the animal. Then suddenly the temperature rises up to a very high degree, reaching sometimes 107° F. It is rare that the fever increases only gradually, rising every subsequent day higher and higher until it has reached its maximum. The fever now keeps on for the next few days, and notwithstanding the high temperature very rarely outward symptoms are met with before the last few days till death. The fever period averages about thirteen days. The minimum period was six days and the maximum twenty days.

The symptoms during life are not very marked, so as to be able to diagnose the disease to be one of East Coast fever

under all circumstances. Loss of condition is almost the first sign. Towards the end loss of appetite, stopping of rumination are noticed. In addition to this comes an increased secretion of the different glands of the head, showing itself in slight running of the eyes, dropping of saliva from the mouth, and even discharge from the nose. In many cases diarrhœa is present. The sum total of these symptoms forms a picture similar to Rinderpest, with the difference that the secretion is not so intense as in the latter disease. Some animals show also a swelling of the lymphatic glands of the head and throat. The animal may die suddenly seized with fits, or after a prolonged coma. The uncertainty of the outward symptoms necessitates a microscopical diagnosis, which, as shown before, is possible in every case; the number of parasites being present in enormous quantities at that particular period of the disease.

#### NATURE OF THE DISEASE.

The post-mortem reveals some typical lesions. There is, in many instances, an œdematous condition of the lungs. The œdema being so strong that white foam protrudes from the nose, this phenomenon and the collection of the liquid in the lungs resemble very greatly the disease commonly known as horse sickness. There may or may not be a collection of liquid in the pleural cavity and also in the pericardium, accumulating, sometimes, in rather large quantities. It is due to this symptom that the disease is sometimes mistaken for heartwater in cattle, another South African tick disease. There is often a hemorrhagic inflammation of the pleura of the lungs and of the ribs, and very often hemorrhagic infarcts in the lung tissue.

The liver is nearly in every instance involved in a process of disintegration. That organ is usually enlarged and changed in colour; a jaundiced state is generally noticed, sometimes only hyperemia, but usually also a fatty degeneration is present. The specific appearance is presented by the so-called white infarcts. They are present only in the minority of cases, but sometimes are so numerous that the liver has a mottled aspect. These infarcts are small patches of local necrosis. The bile is usually changed in colour and consistency, as may be expected from the condition of the liver. This circumstance led to the popular belief that the disease was gall-sickness, which it may be remarked is the name commonly given by farmers to all diseases of the liver without distinction. The spleen is occasionally enlarged, rarely in the cases of pure bacillary infection, but nearly always after the *Piroplasma bigeminum* has made its appearance, in which instance the general aspect of ordinary redwater is apparent. The kidneys also show in the majority of instances typical lesions in the form of infarcts. These are usually white, sometimes red, or mixed in colour, protruding slightly over the surface, and giving that organ a mottled appearance.

A peculiar phenomenon of this disease are lesions of gastroenteritis, sometimes so well pronounced that rinderpest is suspected, the principal difference being the absence of necrosis of the Peyer patches of Rhodesian tick fever. In addition to these symptoms comes the enlargement of nearly all lymphatic glands, the collection of serous liquid in the serous membranes, usually a general anæmia, and sometimes a jaundiced condition. The blood cells show nothing particular microscopically.

#### SUSCEPTIBILITY OF THE DIFFERENT BREEDS OF CATTLE.

In the introduction of this paper it was stated that East Coast fever was first noticed to cause serious damage to imported cattle. In the Transvaal, however, the first observers found the disease amongst native stock accustomed to all conditions of climatic influence and change of pasture. The importance of these observations was not given due place, and is still overlooked. The cattle which sickened first in Komatipoort were low veld cattle—viz., cattle which for the last two or three years had been on pasture where freshly-imported stock from the high veld do not thrive well. It is quite true that the disease was carried to our immediate neighbourhood by imported cattle, but it was also conveyed by low veld cattle. But before all these facts were realised a certain series of experiments were undertaken with the intention of guiding us on to some practical plan for the importation of cattle for the purpose of re-stocking the country. We exposed several lots of cattle coming from many different localities. Cattle born in the Transvaal, cattle from the redwater regions of the Cape, cattle from Madagascar, cattle from Somaliland, cattle imported from Texas and supplied by the Land Department, cattle from Queensland, were exposed to natural infection, with the result that they all succumbed to the disease within the typical incubation time. On the suggestion of Mr. Stockman, Principal Veterinary Surgeon for the Transvaal, who had observed that buffaloes have much resistance to Texas fever in India, an Indian buffalo and an Indian ox were exposed, with the result that they both contracted the disease and died. This experience has some significance for us, inasmuch as that we may expect that the rare South African buffaloes will finally meet with a like fate.

Rinderpest ravaged the buffalo species; it can hardly be hoped that the scattered remnant will survive a second insidious decimating disease.

Again, on the suggestion of Mr. Stockman, camels were exposed to the strongest infection we could possibly find, and the experiments which have been conducted so far have shown that they do not contract the disease. In the future it may become necessary that we substitute for our oxen, which cannot live in infected areas, some other animals. Experience has proved that the camel is quite suitable. So far as our observations go, game, such as wild bucks, do not contract the disease,

neither do horses nor asses nor their hybrids; neither do sheep nor goats.

The disease is limited to the bovine species.

#### MORBIDITY AND MORTALITY.

Our experience shows that in a badly-infected area no susceptible animal escapes the disease, and therefore we can safely put the morbidity at 100 per cent. It is quite true that for a certain period some cattle may escape the disease for some reason or other, even on a badly infected place, but finally they do contract the disease. We have observed that some cattle, exposed to the strongest infection obtainable, lived for some months, whereas their mates exposed at the same time died within the typical time. We certainly do not go very far wrong in stating that all cattle are susceptible to East Coast fever.

Concerning mortality, we have the experience of the above mentioned lot of a thousand Australian cattle which all died. We have in the Transvaal many a sad case illustrating the pernicious nature of East Coast fever. It may be interesting to quote the incident at Komatiepoort, where, out of five hundred Africander cattle, only twenty-four survived, equal to less than 5 per cent. This figure may be accepted as the average recovery. This percentage is equal to that of rinderpest, with the essential difference that rinderpest is a contagious disease which has disappeared, while East Coast fever is destined to remain. The total loss from this disease in South Africa may be estimated at over thirty thousand head of cattle.

#### NATURAL PROPAGATION OF THE DISEASE.

East Coast fever being a piroplasma disease, led investigators to believe that it must be carried by ticks. All evidence about its originating and spreading pointed to tick infection. Mr. Lounsbury, the Cape Entomologist, was the first to prove that a certain species of tick communicated the disease. This tick is what is now commonly called the brown tick (*Rhipicephalus appendiculatus*). The name brown tick is derived from the colour of a male or an unengorged female. This is a very common tick in the low veld, where it attacks all species of domesticated animals, but preferably the ox. The favourite resting place of this tick is inside the hairy margin of the ear, where it may sometimes be found in scores. It is but rarely met with on the body of an animal. The tick seems to prefer the warmer districts where there are bushes present. It becomes rarer on the higher altitudes, and is not found on the high veld. The tick was in the country before the disease was here. Coast fever, therefore, found the necessary condition for its propagation. The life-cycle of the brown ticks is as follows:—The engorged female drops off a beast, hides herself, and, after a few days, averaging about five, she begins to lay eggs. This may last many weeks, then the female's body

gradually becomes retracted, discoloured, and she finally dies. She remains alive sometimes as long as till the time when the eggs are already hatched. The eggs laid number several thousands. They are egg-shaped, and of a brown colour. During the incubation period, while the young tick is hatching, the shell of the egg undergoes a transformation in its colour. Presently a white spot is noticed, about the middle of the egg, which corresponds to the anus of the larva inside. The brown colour gradually fades away and becomes white, when the shell breaks, and the freshly-born larva creeps out. The hatching period varies according to the season. It averages about 60 days; in summer it may be shorter, and in winter time it is longer.

The newly-hatched larva has six legs. It crawls slowly at the beginning on the egg shells. Its body, mouthpiece, and legs are whitish and soft. Gradually the colour changes into brown, and the little creature becomes stronger and more active. It now creeps away from its hatching place, not very far, however, but climbs to the top of grass and bushes. Here it awaits its chances to find a host. As a rule it keeps quiet, but becomes very active when disturbed, and it may then be seen to stretch out its forelegs to catch the passing host.

It is endowed with longevity. Larvæ kept in glass bottles will live at least three months, and probably even longer,

After having found a host, preferably the ox, the larva begins to suck blood. I have made in my laboratory a series of observations which show that a minimum of four days are required for the repletion; but sometimes a week and even longer. The engorged larva now drops and hides away in the ground. The colour of the larva directly after sucking is dark blue when pure blood is imbibed. It may be more or less red and even quite white when the nutriment is derived from the blood plasma or the lymph. When kept in a glass bottle the engorged larva crawls around the first few days, and then settles down, to undergo the moulting process.

Discoloration begins at the mouth part, which becomes white, and from thence the whole body is gradually involved. After about four weeks, sooner in summer and later in winter, the skin is cast and the new creature, with eight legs, the nymph, emerges. It is larger than the original larva; and, just as the larva was after hatching, is colourless. During the next few days the brown colour appears, and the young creature crawls about to look for some resting place, where it will wait for a host in the same manner as the larva did. The nymph is likewise endowed with longevity, and lives in the glass bottle at least three months, but probably longer under natural conditions. When a host is found the repletion of the nymph begins, which usually lasts from four days to a week. The engorged nymph drops again, hides away, undergoes a moulting process, which in its outside aspect is similar to the one in the

larva, and after a lapse of about a month, sooner in summer and later in winter, the adult ticks appear, either as male or female. Neither larvæ nor nymphæ have sexual organs. The adult ticks which emerge from the nymphal skin are almost colourless, but within a very few days the normal brown colour appears. The tick becomes stronger, and is soon on the lookout for a host. It may be found in the field on the top of grasses motionless, but as soon as it is disturbed the front legs, which serve as feelers, are moved about to seek attachment.

As already pointed out, the sexual adult ticks are principally met with in the ear, whereas larva and nymphæ attach themselves to any part of the body. The adult tick which does not find a host may live for many months; such ticks can easily be kept in the laboratory for over three months, but as soon as they have been feeding once and have left the host they usually die within a very few days. The sexes mate on the host after a few days, and not unless the male and the female have had a good feed first.

The fertilized female engorges now rapidly, and may within a day reach an enormous size. She drops usually from the fifth day, hides away, and begins laying eggs. The male remains on the host, and may be found there after months. The female which does not find a male does not engorge, and may then also make a long stay on the host. Thus the brown tick has in his life-cycle to feed three times, for which purpose he really needs three hosts; accordingly, the conditions for his propagation are not very favourable. The transmission of the disease is carried out by this species of tick, not in the manner as is generally believed, viz., that a tick feeds on a sick beast and then crawls over to another, into which it injects the poison. The adult tick when once he has found his host does not leave him, or then only accidentally or when the host dies. But ticks collected from dead and sick cattle and placed on healthy cattle have, in my experiments—and they were made at least on a dozen animals—failed to produce the disease. There is only one successful experiment carried in the way indicated on record, that is by Mr. Lounsbury, with ticks taken from dead cattle at Nelspruit.

We may take it as granted that once a tick has bitten it has discharged the infection. In Mr. Lounsbury's experiment probably a tick was used which had not yet been feeding. It was thought at the beginning that the infection would be taken by the adult female and then be passed through the egg into the larva, as is the case in Texas fever, but Mr. Lounsbury's experiments as well as mine have failed in this respect.

Again, judging from analogy with biliary fever in dogs, where the infection is taken by an adult female, passed through the egg, through the larva and nymphæ, again into the adult stage, and so finally producing the disease, it was thought that the sexual tick was the only one capable of producing the dis-



ease. But such experiments gave negative results. On the other hand, all experiments undertaken with adults which had been feeding as nymphæ on sick cattle succeeded.

I have been able to produce the disease in this way in eight different oxen. The adults, of course, might have contracted the infection either in their larvæ or in their nymphal state. Therefore I took nymphæ which originated from larvæ that had been feeding on healthy cattle. The mother tick also came from healthy cattle. I placed them on a sick ox. After moulting they produced the disease in four oxen, thus proving that the infection can be received in the nymphal stage and communicated in the adult stage. The same observation was made with regard to larval ticks which originated from healthy cattle. They were fed on sick cattle, and after moulting they were placed as nymphæ on healthy cattle. Two oxen which were experimented with in this way contracted the disease and died.

Thus East Coast fever is transmitted by the nymphæ and adults of the brown tick. An important factor to ascertain was whether an infection which was received by larvæ could be passed through nymphæ into the adult. In other words, whether a tick could communicate the disease twice. Two experiments were made where adult ticks which as nymphæ had produced the disease were placed on cattle, but they failed to pass on the disease.

Although we have to repeat these tests on a larger scale, the experiment indicates that a tick communicates the disease probably only once in its life cycle. Field investigations seem to point to this, inasmuch as it is an every-day experience that only cattle spread the disease, but not horses or other animals, although they may carry the ticks. I have further ascertained that it is the tick which is feeding on an animal during the time when the piroplasma is in the blood which carries the disease, and not the tick which drops during the incubation time. With regard to the quantity of ticks required, my experiments show that two ticks are quite sufficient to cause the malady to appear in the typical period. Probably one infected tick would be able to do the same. Therefore not many ticks are required to infect a farm. The question whether other ticks will also cause the disease is an important point, since the Blue tick (*Rhipicephalus decoloratus*), the Red tick (*Rhipicephalus Evertse*), and the Bont leg tick (*Hyalomma Aegyptium*) are very common, and are found in nearly every part of the country. I have tested blue ticks on six different oxen with negative results. Similar was the experience of Mr. Lounsbury, who also failed in every instance to produce the disease. The blue ticks behave quite differently from the brown tick. The larva which has found a host moults into a nymph, and the nymph into the adult on the same host. Therefore, the infection would have to go through the egg, as it does in Texas fever.

This is not, however, the case with the brown tick, and therefore much less with the blue one. The red tick has also proved to be harmless. This tick leaves its host as a nymph, it moults as larva into a nymph in the inside of the ear. I have collected such nymphæ from sick cattle and placed them on healthy cattle as adults, but failed to transmit the disease. The bont leg tick is most difficult to rear. It is only found as an adult on cattle. Larvæ will not bite, and nymphæ are not yet known. We may safely exclude this tick.

There is, however, another species (*Rhipicephalus simus*), commonly called the black pitted tick. It is very common on dogs, sheep, and goats in the low veld, and is also met with on cattle. Its life cycle corresponds exactly with the one described for the brown tick. It may, therefore, reasonably be expected to be one of the carriers of infection. An experiment in this direction proved that the disease can be communicated.

Larval black pitted ticks, whose mothers were taken from dogs, were fed on a sick ox. The nymphæ which resulted were placed on a healthy ox, which sickened in due time and succumbed to the disease.

This experiment is conclusive, because the disease could only have been transmitted in the way indicated. The bont tick (*Amblyomma Hebraeum*), well known as the carrier of Heart-water in cattle and sheep, may also be reasonably suspected as one of the carriers, but proof is still lacking. An important question which awaits solution is whether oxen which have recovered from East Coast fever are also able to spread the disease by means of tick infection. There are many analogies to enable us to accept such a supposition. But experiments are still wanting to support this hypothesis. It will be seen from these foregoing notes that the disease will spread through such parts of the country where these carrier ticks are met with. We are thus able to forecast the different localities of infection by ascertaining what species of tick inhabit these places. I have already pointed out that the disease did not spread to the high veld—this probably owing to the fact that ticks are not able to live there.

During an exceptionally warm summer and under specially favourable conditions a generation might live and breed there. But the cold winter will doubtless kill them. Even in Pretoria I have great difficulty in breeding brown and black pitted ticks during the winter. Many attempts during that season have failed, the eggs not even hatching.

We are certainly on the safe side in saying that the disease will not spread throughout the whole of South Africa, but only through such localities where the particular disease-carrying ticks are found.

#### IMMUNITY AND INOCULATION.

I have already pointed out how small the percentage of



recovery is in East Coast fever. Animals which had gone through the disease may be considered as immune. I have at repeated intervals tested a number of survived cattle. They were exposed to the worst infected locality, and the result was that they did not contract the disease a second time. This experiment was made with ten oxen, and has lasted about a year, and is still in progress. The conclusion is, therefore, that once immunity has been established it is a permanent one. Reference has already been made in this paper that the disease has originated in the East Coast of Africa, where the disease has been permanent since bygone ages. A study of the condition there will therefore throw some light on the immunity of cattle against this disease. Cattle born and bred in these regions are immune against the disease. Cattle brought into the area contract it and die. It was probably the law of the survival of the fittest that made the coast cattle immune, and it is probable that the progeny of the cattle acquired some immunity from their parents. This immunity became active, that is to say permanent, under the influence of the constant exposure to natural infection. It must have taken a long period for East Coast cattle to acquire this immunity. The same result will finally be achieved here. But it must be borne in mind that 95 per cent. of the present cattle, living in localities suitable for the development of the infection carrier, must first die, and that the re-stocking of the country with immune animals must start from the surviving 5 per cent.

In addition to this the country will probably remain infected for all time to come, and cattle brought into these parts from without will contract the disease. This is a disheartening outlook, and warrants the most stringent measures to stop the spread and to stamp out the disease. Now, as already mentioned, inoculation with any material taken from a sick animal and injected into a healthy one fails to produce the disease. This fact demonstrates the difficulty of finding a successful inoculation.

Professor Koch has laboured to find such a method of inoculation, and he has already proposed a plan of conferring immunity. According to his last report, this immunity would only be complete in about five months after the animal had been inoculated. During this time the inoculation has to be repeated at intervals. Professor Koch recommends repeated inoculation with blood from animals which have recovered from the disease. And he has shown that after inoculating susceptible animals with either sick or recovered blood certain forms of endoglobular parasites appear. These organisms he designates as ring-forms. He draws his conclusion regarding immunity from the appearance of these rings, which he considers identical with the spherical forms of the piroplasma in East Coast fever. Indeed, he has also shown that such rings are found in the blood of immune cattle, and he recommends

such blood for inoculation. The observation is undoubtedly correct. But I am able to show that this phenomenon does not apply to East Coast fever alone. We find typical rings and also bacillary forms of piroplasma in connection with ordinary redwater.

I have already stated that we are able to produce ordinary redwater by injecting the blood of an immune ox into susceptible animals. The fever will appear about a week or ten days after the injection, and during the reaction we find the typical *Piroplasma bigeminum* in the blood. Some of these animals a few weeks later show a second reaction, which may be so strong that some of them succumb to it. During this reaction the typical *Piroplasma bigeminum* may appear. In some cases, however, quite an atypical parasite appears in the shape of small rings and bacillary forms, typical of East Coast fever. They may be so frequent that the diagnosis for Rhodesian tick fever would be justified. Personally, in one case I had some slight difficulty in explaining how one particular ox, treated in the way indicated, should have contracted the new disease. If the second reaction was really Coast fever, then immunity should have been the result. To clear up this matter, infected ticks were placed on the ox, with the result that it contracted the disease and died of symptoms in every respect typical of Coast fever. Hence the conclusion that the parasites which resembled the Coast fever piroplasma had nothing to do with it. But this is not the only observation. I inoculated three calves for redwater, which were born on the premises of the laboratory. Some weeks later a secondary reaction set in, and afterwards rings appeared, and are at the present moment still found in the blood. I have still further proof. A number of freshly-imported cattle from England were inoculated against ordinary redwater. They went through the typical reaction, and some weeks later they had a second reaction. Shortly after this second reaction blood smears were examined, with the result that the typical rings were found in some of the cattle, whereas they were not found in the blood of animals which were never injected.

To me the occurrence of rings is now an every-day experience. A certain series of experiments was undertaken in connection with heart-water. The cattle used for this purpose had some time previously been immunised against ordinary redwater. The inoculation of heart-water virus brought on a reaction and caused the death of some oxen. In almost every one of them rings and bacillary forms were noticed. Thereupon I began to examine the blood of many oxen. These oxen had at one time been used for the production of rinderpest serum; accordingly they were highly immunised. This is done by the injection of virulent blood. With the exception of a few animals rings were seen in their blood. I have also treated oxen in the way indicated by Professor Koch, and after a

weekly injection of immune blood the rings appeared. Some of the oxen had them before the injection had begun. The startling fact, however, is that two oxen also showed an increase of rings. They had been injected with blood from an animal which was not immune against Coast fever, but which showed the rings during a heart-water reaction in rather large quantities. These observations, to which I could add many others, led me to believe that the appearance of rings after repeated injections of blood is not typical of Rhodesian Tick fever, but is a phenomenon due to the injection of blood from a red-water immune animal. I am inclined to believe that the rings are nothing else but a form in the life-cycle of *Piroplasma bigeminum*. Probably the dormant form in the immune animal. Hence I conclude that the appearance of rings in the blood proves that such an animal is immune against ordinary red-water. That animals treated in the way indicated by Professor Koch acquire immunity against Rhodesian tick fever only after five months, a fact which has not yet been proved, lends support to the view I hold on this subject.

At the last congress of Veterinary Surgeons and other representatives of all the South African Colonies, Professor Koch made a statement to the effect that he found the typical rings in the blood smears taken from oxen in East London and from Natal, but not in smears received from Cape Town. He therefore concluded that the whole South African East Coast is infected with the new disease. Such is, however, not the case. The rings Professor Koch has seen in the blood are, I consider, the forms of immune *Piroplasma bigeminum*. Natal and East London are red-water countries: the Cape is not. We will find these rings in the cattle from Natal and East London, but not in cattle from Cape Town. The number of rings in a sample of blood varies much. During febrile reactions they may increase and invest a considerable percentage of the red corpuscles.

Usually, however, they are rare, and a careful examination is necessary. The true nature of these rings is shown by the use of double stains, whereby the chromatic body takes the characteristic colour.

The stains Azure II. and Dr. Maconkey's modification of Romanowsky's, give in nearly every instance a clear definition, and deserve to be recommended.

#### TREATMENT.

All attempts to cure sick animals have so far failed, in spite of the many trials that have been made with various drugs, which might reasonably have been expected to destroy the micro-organisms of the disease. The serum treatment adopted by Professor Koch has failed, since the serum produced by the injection of large quantities of sick blood into immune animals resulted in the rise of haemolytic serum. When injected into sick cattle this serum caused rapid death by the

dissolution of red blood cells, whereas the same serum injected into healthy cattle is harmless. This fact from a scientific point is highly interesting, whilst at the same time very disheartening for the investigator. The inoculation introduced by Professor Koch has not yet stood the test of extensive field experiments, and as the immunity is only expected after a period of five months the practical value of this method is limited. If, according to Professor Koch, immune cattle carry the infection in their blood—a theory highly probable, and which still remains to be proved—then producing immunity is of little value, because these same cattle keep up a constant and permanent infection of the veld. The maintenance of the disease would constantly debar us from exporting cattle. In addition to this the inoculation as recommended by Professor Koch involves a certain danger to imported cattle, as with such blood other diseases, such an ordinary red-water, trypanosomiasis, and heart-water may be produced. Before the danger of immune cattle is settled, in an unmistakable way, the Transvaal Veterinary Department is not prepared to recommend any inoculation. The only successful way to stop the spread of the disease is a complete restriction in the movement of cattle from sick farms. It will therefore become necessary not to restock such a farm for some time to come. On the other hand, there is hope that such a farm may be cleansed after a certain period. It is recommended that other stock than cattle be placed on the infected area. The infected ticks will feed on such stock, and as there is no chance of re-infecting the tick the disease must naturally disappear. We have an experiment to support us in this view. Mr. Stockman, the Principal Veterinary Surgeon, and myself exposed ten head of cattle on a fenced-in portion of a farm near Nelspruit, where fifteen months ago the disease was rampant. After an exposure lasting over four months none of the cattle died of East Coast fever, whereas all the control cattle on an adjoining farm, which was infected, were wiped out. The isolation of infected farms will become an absolute necessity, and the best way to secure such an isolation is by fencing in. Transport will have to be regulated, and no susceptible draft animals, such as horses, mules, and donkeys should be substituted for oxen. On the recommendation of my colleague, Mr. Stockman, camels were imported. They proved to be immune against East Coast fever, and it is hoped that they will render good service in infected districts. Dipping of cattle exposed to infection was thought to be a panacea against the disease.

When suitable dipping material is used and the operation properly carried out the infection is retarded. But although we are able to destroy the tick on an animal, we are not able to prevent fresh ones re-infesting cattle, and since a few infected ticks are sufficient to cause the disease the difficulty of keeping them off becomes apparent. When, however, the removal of

cattle out of an infected area is practicable, then every chance exists of getting rid of the infection, and dipping and spraying will prevent the re-infection of the new ground. But the movement must be continually kept up.

For the present all that is possible has been done. But so far we have failed in the majority of cases in convincing our farming population of the seriousness of the situation. It is only by severe and vigorous legislation that we can hope to retard the spread of the disease and to confine it to the present centres of infection. We still hope that the progress of science will assist us to combat the disease in a more economical and more effective way. We still hope that the advancement of science will open to us new ways of combating this ravaging disease in a more economical and effective manner, and eventually freeing our land from a decimating scourge which threatens to ruin the principal rural industry.

## 16.—BACTERIOLOGICAL AND OTHER ASPECTS OF MINERS' PHTHISIS.

By L. G. IRVINE, M.A., M.D., B.Sc.

(Plates IX., X., XI., XII., & XIII.)

To those of you who are resident in Johannesburg, and have interested yourselves in the matter, the subject of Miners' Phthisis may possibly appear to be one on which a great deal has been said already, without our having attained to any very great certainty regarding it. But although the subject has been handled certainly by many, it has not yet been thrashed out. And accordingly, when I was invited by the secretary to read a paper on "Bacteriological and other Aspects of Miners' Phthisis" before this section of the South African Association I accepted the invitation, not with the idea that I could claim to make any final pronouncement, but in the hope that a brief statement of the present state of investigation into the nature and causation of this disease, which has been responsible for so heavy a mortality amongst the miners on the Rand, might prove of interest, even although it should contain little or nothing that is quite novel. One thing, however, I wish to say at the outset, which is that I do not pretend to claim for this paper the character of an exhaustive study of the subject. The necessary limits of the time at my disposal permit me to refer only to its more salient features. Statistics I have left practically aside, and many other matters of interest I shall pass over or merely mention without discussing them. I say this partly in order to disarm criticism, which, should it arise, will, I hope, be concentrated rather on what I say than on what I leave unsaid.

And first let me define what I mean when I speak of "Miners' Phthisis." It was only during and after the war that the excessive mortality amongst the miners, and especially the rock-drill miners, on the Rand, first attracted serious attention. When work was again begun on the mines it was found that, of the rock-drill miners who had been employed by the various mining companies before the outbreak of the war, over 16 per cent. had died, while during the first twelve months after the resumption of work many of the remainder went to swell the grim total. Naturally both the miners themselves and their employers became alarmed, and asked for an investigation into the causes of this high mortality.

And when this investigation was first made it was found that the disease from which these men had mainly died was quite definitely a lung disease. The same feature, indeed, characterises other mining communities in all parts of the world to a greater or less extent. Cornish miners, as was shown more than twenty years ago by Dr. Ogle's oft-quoted statistics, have a mortality from respiratory diseases nearly three times as great as that of all males between the ages of

25 and 65, the comparative figures being 2,065 to 723. And further, it was apparent that this disease from which the miners suffered was a chronic one, characterised by a progressive consolidation of the lung tissue with accompanying catarrhal processes, and that while its onset was extremely insidious its termination was often painfully rapid.

It is to this condition, then, that the name Miners' Phthisis was applied, and personally I think the term is both suitable and useful. But it must be thoroughly understood that this term is primarily a clinical one, and carries with it no pre-suppositions as to its causation or its pathological nature. The chronic lung diseases which one meets with amongst miners, and which one includes under the name of Miners' Phthisis, have in common the clinical features which I have mentioned. But even in clinical type they present several varieties, which are due to the preponderance in individual cases of one or other of the main causative factors which contribute to the pathology of the disease. And therefore if we may usefully group the chronic lung affections of miners which are characterised by these common features, and which are due to causes incident to their occupation, under the one name, Miners' Phthisis, we must at the same time admit that the term does not describe a specific disease due to a single causative factor, but is a name carrying implications which are primarily clinical, and which does not exclude the possibility of there being more than one agent concerned in the production of the pathology and symptomatology of the disease. If this is thoroughly understood, the use of such a general and, pathologically speaking, indefinite term as Miners' Phthisis is not only defensible but useful, if only to emphasise the fact that few cases of chronic lung disease occurring in miners, who have spent many years underground, are of quite unmixed causation or are the manifestations of a single uncomplicated pathological process.

The provisional report of the Committee of the Transvaal Medical Society, followed by the fuller investigation of the Miners' Phthisis Commission, has made clear certain points, which I may briefly resume.

1. That, as I have said, the excessive mortality of the miners on the Rand has been mainly due to a chronic disease of the lungs, characterised by a progressive fibroid consolidation of the lung tissue with coincident processes of catarrh, and differing in the majority of cases in many respects from ordinary tubercular phthisis.

2. That while no class of miners is exempt from the disease, provided that their mining life has been sufficiently prolonged, its incidence has been found to be greatest and its development most rapid amongst rock-drill miners. Of those who had used rock-drills more or less continuously for seven years or upwards, very many were found to die between the



ages of 30 and 40, and many about the age of 35, while those who had not been rock-drill miners and who had nevertheless died of the disease had a considerably longer mining life, having an advantage probably of 10 or 15 years. Speaking generally, and taking the average, one may say that only a minority of miners who have worked rock-drills for a period of not more than five years show decided evidences of the disease, although no doubt it is gradually developing from the commencement. Yet Dr. Macaulay showed me a case the other day of a miner who had been employed on rock-drills for three years only, but under the worst conditions, and who was already permanently unfitted for further underground work—he had well-marked miners' phthisis. He had previously been a quarryman and an iron-stone miner. From six to nine years' rock-drill work under local conditions is, however, usually sufficient to seriously impair or even to exhaust the working efficiency of the miner, although as a rule the number of years spent on rock-drills does not represent the total mining life of these men. These are average statements, of course. Quite recently, in contrast to the instance I have just cited, I saw a man who had worked rock-drills for 10 years in Australia and for 7 years in South Africa before the fatal balance began to tip decidedly against him. Very much in this matter of the duration of working efficiency depends on particular circumstances, the physical equipment in lung capacity with which the miner starts, his personal habits, the degree of continuity of his employment, and the character of the mines and of the mining processes in which he has been employed.

3. That in all the fatal cases in which post-mortem examinations were made extensive fibrosis of the lungs was found encroaching upon and replacing the true lung tissue, and in most cases this was very extreme. The type of fibrosis was that well known to be caused by the continuous inhalation of fine dust, and the conclusion that *the basis of the disease is a silicosis*, a rock dust disease, was confirmed by microscopical examination, which in every case investigated showed the presence of mineral particles to be directly associated with the process of formation of the fibrous tissue. The distribution of the fibrosis coincided exactly with the distribution of mineral matter, and both initially followed the distribution of the lymphatic drainage system of the lungs.

This conclusion was strengthened by the fact that the classes of mining work which were admittedly most dangerous, namely, rock-drill work, and particularly driving and raising, were precisely those in which the quantity of dust generated in drilling was greatest. The further fact, that these operations were also those in which contamination of the mine air by the gases produced by the explosives used in blasting most readily occurred, was not overlooked.

4. That in a certain but undetermined number of cases,



forming, however, a minority of the whole, a true tubercular phthisis co-existed with, or was superimposed upon, the primary silicosis.

5. That the contamination of the mine air by certain noxious gases, particularly those produced by the nitro-glycerine explosives used in blasting, was a contributory and aggravating factor in the production of the disease. Of these gases carbon monoxide was stated to be the most dangerous, but nitrous fumes were also regarded as being in a minor degree contributory.

These are the broad conclusions to which previous investigation has led us, and with them I agree. The difficulty all along has been to determine what is the relative importance of these three main factors, dust, infective processes, and noxious gases, as causative agents in producing the diverse pathological processes and the symptoms of Miners' Phthisis. And what I wish to do to-day is to give some idea of what I believe to be the rôle which these various agencies actually play, and particularly to correlate the several clinical types of the disease as we meet it with the varying preponderance of one or other of these three main factors.

#### THE INFLUENCE OF DUST.

That the more or less continuous inhalation of fine dust is an efficient factor in producing both catarrhal processes in the air passages and alveoli and fibroid changes in the substance of the lungs is a pathological fact so well established that I need here adduce no further evidence in its favour. It may be sufficient to remind you that earthenware manufacturers, working under conditions which induce the inhalation of fine silicious dust, but which certainly do not include the influence of noxious gases, suffer from the disease known as "potters' phthisis," which is a true silicosis, and which in many respects closely resembles the "miners' phthisis" which we meet with on the Rand. Earthenware manufacturers have in England a mortality from phthisis and respiratory diseases almost identical with that of Cornish miners, the comparative figures being 1,118 and 1,148, both far above that of any other occupied class. *Of all the dust diseases silicosis is the most fatal.*

Nor need I do more than mention the facts, that the dust of the Rand quartzite is admittedly a hard dust, and that it appears under the microscope in the form of silicious particles, many of which are exceedingly fine and sharp and angular. The great majority of the gold mines of the Rand also must be classed as dry mines. These facts no one disputes, and anyone who has had experience of underground work under local conditions will agree also that the mine atmosphere is everywhere charged with dust in an abnormal degree. Still more so is this the case in drives and rises. In a rise when

drilling is going on the air may be felt to be quite oppressive with dust, and in a drive, which is the next worst, Dr. Pakes demonstrated the presence in the air of dust to the amount of 0.5625 grammes per cubic metre while drilling was going on.

Now there are three main clinical types of miners' phthisis, which we medical men have been accustomed amongst ourselves to distinguish as the "dry type," the "moist type," and the "very chronic type."

Take, for example, such a case as the following. Last September a miner, T.H.A., consulted me. He was 40 years of age, and had had a mining life of 24 years. Of this he had spent 12 years elsewhere, mostly in iron mining at home and in the United States, with a short spell of gold mining in America. He came to South Africa in 1890, and with one short holiday worked on the Rand as a miner for nine years, of which more than five were spent in rock-drill work, and all of this in developing. He had worked a good deal in "bad places," and he had been "gassed" once, and he believed that he was for some time thereafter more readily affected by the fumes of explosives than most other men. His partner during this work had since died of chest disease after eight years' rock-drill work. He went home and did nothing during the war, and he returned to South Africa in 1902. He stated that at that time he was not noticeably short of breath, he had no night sweats, and no spit.

He worked underground for precisely five weeks, when he had to give it up, and had since been employed as banksman at a downcast shaft, so that there had been no recent exposure to the influence of mine air. But he steadily lost weight, he had "no wind," he could not walk a hundred yards without getting short of breath, and he suffered, as he said, from perpetual indigestion.

He was pale and much emaciated; his chest expansion was one inch. There was evidence of consolidation, especially at the right apex and the left base, with signs of a dry cavity under the right cavicle. What struck one on auscultation was the poor entry of air all over the lungs (especially posteriorly) and the absence of moist sounds. These, which are indicative of active inflammatory processes, were present slightly in two areas only. He had old friction sounds here and there, indicative of past dry pleurisies. He had slight dry cough, but he had no spit. His complaint was that he could not spit. He had no fever, no night sweats, he had never spat up blood. The pulse rate was somewhat accelerated (85 to 90), the heart sounds, however, were normal; the arteries were not thickened; he had no albuminuria.

Now I have described this case to you because it is so very typical of what we call the dry type of miners' phthisis, which is the commonest and most characteristic form of the disease. It is "dry" because there is little or no expectoration, which

is tantamount to saying that there is little or no active inflammatory process present. Progressive emaciation and urgent breathlessness were the main features of the case, and to these was added, what patients of this sort often complain of, perpetual indigestion.

Note, now, in this case, the very slight expansion of the chest, one inch difference in all between the extreme of inspiration and the extreme of expiration. In such cases, indeed, the tape measure forms a most valuable prognostic. Sometimes the expansion may not even be an inch. The deepest inspiration possible may be a mere shallow gasp, which scarcely serves to increase at all the capacity of the lungs. The rigid chest, with its diminished expansion, indicates a condition of the lungs in which there is little breathing capacity left to come and go upon. Note the rapid decline in health on the resumption of underground work. One sees case after case of this sort. The breathing capacity, already seriously encroached upon by the fibroid change, is just sufficient to maintain health under the most favourable conditions. Work underground, with its attendant aggravations of catarrh, and the deleterious influences of a vitiated mine air, proves more than the lungs can cope with, and a rapid decline in health follows. Yet previous to this exposure the patient in such a case as I have described feels tolerably well; a little short in the wind, perhaps, for the fibroid encroachment is primarily a mechanical and a nutritive disability. No infective process is at work, there are no toxines present to act as constitutional poisons and also as danger signals. The main disability is the diminished respiratory capacity. And this leads one to remark that a man who starts with a good respiratory capacity has greater chances in his favour, greater breathing space to come and go upon, than a man with a poor capacity and but a small margin of surplus breathing space. Expose both to equal underground risks, and especially to equal risks from dust, and the former will inevitably last the longer because of his valuable initial advantage. Personally I always advise a young miner whose respiratory capacity is poor at the outset to change his occupation while he can.

And finally note in such a case the absence of the typical signs of tubercular phthisis, hectic fever, haemoptysis, night sweats, and free expectoration.

Cases of this dry type are, I believe, examples of a pathological condition in which a silicosis is the predominant feature. It is uncomplicated by any infective process. Such a case, indeed, cannot be mistaken for a case of tubercular phthisis, and the scanty sputum, which may contain silicious particles, contains no tubercle bacilli.

Let us suppose now that the disease proceeds to a fatal termination, maintaining its dry type practically to the end, how, we may ask, does such a patient die? In one of two ways. Either his breathlessness, which is due primarily to the gradual

obliteration of the true lung tissue by the progressive fibroid change, becomes steadily worse and worse until it becomes so bad that he can no longer leave his bed, and he ultimately dies of heart failure with cyanosis and other attendant signs, or suddenly, near the end, the lung with its lowered vitality can no longer resist the invasion of infective processes. An acute pneumonia may supervene and carry off the patient; or pyogenic organisms invade the lung; it breaks down, necrotic cavities form, portions of the lung may become practically gangrenous, and the case passes at the end into the "moist type," which I shall discuss in a moment.

What I have called the "very chronic type" agrees in most of its clinical features with the picture I have outlined. It also is of the "dry type," although chronic bronchitis is a common feature. But it develops more gradually, occurring, as it does, mostly among the older miners, who have used rock-drills scarcely at all or not at all, but who have had a mining life of 30 years or more, and who die at a later age—say from 45 to 50. In such cases secondary affections of the heart and blood vessels and kidneys may be found, and albuminuria and general dropsy accompany the heart failure and cyanosis of the terminal stage.

Now here, in a drawing which I prepared for the Commission, is an illustration of a case of this nature (Pl. IX.). There is very extensive fibrosis of the lung, so extreme, indeed, that it is difficult to realise how life can be carried on at all with the lungs so crippled. The pleura, too, which forms the investment of the lung, is greatly thickened, and was extensively adherent to the chest wall. There is no breaking down of the lung tissue, there were no tubercle bacilli in the sputum, and the patient died of heart failure with cyanosis, dropsy, and albuminuria. His age at death was 52, his mining life had been 35 years, and he had worked rock-drills only for a few months.

Here, on the other hand (Pl. X.), is a sketch of a lung, which very closely resembles that which I have just shown you, with the exception of one important feature. For in this second case the fibrosed lower lobes show large areas of necrosis, forming gangrenous cavities in the substance of the lung. Now the case from which this drawing was made was also almost to the very end one of the dry type; only in the last few days of life did the lung begin to break down and the expectoration become profuse. The age of this patient at death was 34; he had been 23 years a miner, and of these he had spent 7 years on rock-drills.

To sum up, then. Those cases, which during life are clinically of this dry type, and whose lungs show these features post-mortem, are pathologically, as I have said, primarily almost unmixed cases of silicosis. They form the commonest and most characteristic form of the disease. The breaking

down of the lung tissue is in these cases a terminal phenomenon, due to the late invasion of infective processes. All cases of true miners' phthisis are primarily, at least, cases of silicosis. Silicosis is the feature common to them all. I had hoped to show you a series of microscopic specimens illustrating the minute features of the process of fibrosis of the lung in cases of miners' phthisis. Of these Dr. Pakes has now a fairly extensive collection, made from material which various medical men have supplied to him. But the press of the more important duties in which he has recently been engaged has prevented me from carrying out this intention. I must content myself, therefore, with showing you these drawings, which I made some time ago, and which show—the first (Pl. XII.), the early process of formation of the fibrous nodule, the second (Pl. XIII.), a further stage in the process of fibrosis, produced by the growth and coalescence of originally discrete nodules. In both the intimate, and indeed identical, local conjunction of the formation of fibrous tissue with the presence of mineral particles is sufficiently obvious.

#### THE INFLUENCE OF INFECTIVE PROCESSES.

What I have said regarding the acute infective invasion which may suddenly appear as a terminal feature in such cases as those I have described affords one example of the influence of infective processes in miners' phthisis. And this, you will remember, is the second main causative factor contributing to the pathology and symptomatology of the disease. I have said enough, perhaps, regarding this sudden terminal breaking down of the lung. Let me now very briefly mention the influence of other infective invasions of a less acute type.

The first of these is *tuberculosis*. Tuberculosis of the lungs is what is ordinarily called "consumption," and from the first we have recognised that tuberculosis did in a minority of cases become associated with the primary silicosis. This, indeed, is what one would expect. But I believe that, in the great majority of cases in which it does so appear, tuberculosis is a superimposition, a secondary process, and I base this conclusion not only on the pathological evidence at our disposal, but also on the fact that the mining life of a man, who should start underground work with lungs already affected by tuberculosis, would assuredly not be a long one.

Since the Government Bacteriological Laboratories were established in Johannesburg, I have made a point of sending there the sputum of every miner who came to me complaining of chest symptoms for bacteriological examination, and for their courteous co-operation in aiding me in this matter I must warmly thank Dr. Pakes and his staff. As a consequence we are gradually collecting a considerable amount of interesting material. The number of cases is as yet too small to allow one to speak of percentages, for it is only after a prolonged

investigation that one can venture to do so. But this conclusion is already pointed to, that, although in the large majority of such sputa tubercle bacilli are not found, yet tuberculosis does play a prominent part *in the later stages* in a considerable number of cases. And when tuberculosis does become grafted on the primary silicosis, the downward progress of the patient is greatly accelerated. The disease, too, changes its type; it takes on the characteristics of the "moist type." We may find a greater or less degree of hectic fever, we may find night sweats, and we almost invariably find more copious and even profuse expectoration. Moist sounds appear in the lungs, and there is commonly a rapid breaking down of the lung tissue. Tubercle bacilli are also found in the sputum. Yet, post-mortem, one finds little in the naked eye appearances, which differs from those seen in cases of the purely fibroid type, except that the lungs show as a rule more extensive excavation and greater evidences of active inflammatory change. But the cavities are not typical tubercular cavities, but are ragged and necrotic. No doubt the infection is always a mixed one, in which the tubercle bacillus and ordinary pyogenic organisms (and sometimes, perhaps, the pneumococcus) are alike operative.

A case of this sort, where tuberculosis appeared as a secondary feature in the disease, came partly under my own observation and partly under that of Dr. Frazer, who has kindly allowed me to make use of his clinical notes regarding it. It may be taken as a characteristic example of this "moist type" of the disease.

J. F. R., aged 33 years, had been a miner for 20 years, having worked for 5 years in Cornwall and for 15 years in South Africa. He had worked for 12 years with rock-drills on the Rand, with three years' interval during the war, when he was at home and not working. His actual rock-drill work, therefore, occupied about 9 years. He stated that when he returned to South Africa in January, 1902, he was quite well, and he remained actively at work till June, 1903, when he had an attack of "influenza." This illness probably was a genuine influenza, as several others in the same house were simultaneously affected. I saw him about this time and noticed his obvious breathlessness, and that he suffered from cough, although I made no detailed examination of his chest. He never worked again after this attack. Three months later, when he came under Dr. Frazer's care, he was breathless and cyanosed, sleepless, and with no appetite. His pulse was very rapid, and he had paroxysms of coughing. His lungs were full of moist sounds, and there were areas of dulness on percussion posteriorly and at the right apex. Later he began to spit up immense quantities of black matter from the lungs, and the expectoration was found on examination to be purulent and to contain very large numbers of tubercle bacilli. His temperature assumed a moderate hectic type. His downward



progress was rapid, signs of cavity formation appeared at the right apex, his cyanosis and breathlessness increased so that he eventually could not lie down. He died on December 2nd, less than six months after the onset of acute symptoms.

Post-mortem we found the typical appearances presented in cases of miners' phthisis, with the addition of extensive excavation. The lungs were of a dark slate colour. The posterior portions of the right lung were fully consolidated and very fibrosed, and the right apex was replaced by a large necrotic cavity, while breaking down was beginning in the lower lobe also. The anterior portions of the lung were more crepitant, and showed less extreme fibroid change. The pleural cavity was practically obliterated by old and firm adhesions, and the bronchial glands were enlarged and black on section.

The changes in the left lung were similar, and I need not detail them.

The heart was somewhat dilated, but otherwise normal.

No naked eye evidence of tuberculosis was present. The cavities were not typical of tubercular phthisis. Nor did we find microscopic evidence of tuberculosis in the specimens examined. These consisted, however, of only three blocks of lung tissue, and therefore the absence of tubercular change in the portions examined does not preclude the possibility of its presence in other areas of the lung.

Dr. Andrewes, who recently investigated the almost identical disease, which occurs amongst Ganister miners in England, also states that in the lungs there was nowhere any naked eye evidence of tuberculosis. But careful search showed the presence of tubercle as a recent accessory phenomenon, in the form of small miliary tubercles, occurring in scanty numbers, and only in the most advanced areas of fibrous change. Two lungs only, however, were examined by Dr. Andrewes. It is, I think, probable that extended investigation may show results of a similar nature in a considerable number of cases of the "moist type" of the disease as it occurs here.

Here, then, we have a case where an acute infection, influenza namely, apparently determined the invasion of tuberculosis, and definitely initiated the final breakdown, and I think this is not so very uncommon. I do not say that all such cases are equally rapid, for the tubercular invasion may be in some rather less acute, but those which I have seen were rapid enough, and in all but one after the onset of the infection the downward course was steady and uninterrupted.

A further interesting feature of these cases of pulmonary tuberculosis in miners is this, that so far as my observation goes the process is more commonly basal than apical in origin, which is quite the reverse of the rule in uncomplicated tubercular phthisis, but quite what one would expect in cases where the tubercular infection is grafted on a basis of silicosis, which is prone to affect first the posterior and the basal portions of the lung.

Tuberculosis is not, however, the only infective process which is prone to attack these lungs. *Pneumococcal infections* also occur. Pathologists are coming to regard the pneumococcus as being comparable to the tubercle bacillus itself in the protean variety of the infective processes which it may cause. Acute pneumonia, empyema, inflammatory infections of the nasal cavities, suppurative inflammation of the middle ear, and of the membranes of the brain and spinal cord, acute inflammation of the heart, of the intestinal tract, and the peritoneum, and suppurative inflammation of the joints, have all been traced in certain cases to the agency of this organism, which in South Africa we have special reason to dread, and which causes, mainly from pneumonia and meningitis, a grim mortality in our native compounds. But I do not wish to conjure up the terrors of the pneumococcus, but to speak specifically of its relation to miners' phthisis.

It is well known that the pneumococcus is a common enough inhabitant of the mouth and the upper air passages of healthy people, and it has been found also in normal healthy lungs. Not only so, pneumococci obtained in this way from the mouth or nose of healthy persons have been found to produce a fatal septicaemia on injection into animals. In the experimental work which has been done on pneumococcal infection in animals one series of results is of special interest. In these it was found that while the insufflation of the pneumococcus into the trachea did not cause pneumonia, pneumonia did follow if dust were simultaneously injected, or if the animals after being kept warm were suddenly immersed in a cold bath at the time of the injection. This experimental result has an obvious bearing not only on pneumococcal infection in relation to mining life, but also on the epidemics of pneumonia which prevail on the Rand during the cold months of the year, when dust storms are common, and rapid variations of temperature are very frequent.

That an acute pneumonia may attack a miner just as it does anyone else, whom predisposing and exciting causes conjoin to render susceptible to its invasion, need scarcely be mentioned, and that an acute pneumonia, developing in a lung already affected by silicosis, will prove the more dangerous by reason of that pre-existing disability is also obvious enough. But leaving these generalities aside, there are two points regarding the relation of pneumonia to miners' phthisis which I wish to refer to. When pneumonia attacks a lung previously healthy and the patient recovers, the disease terminates by a process of what is called "resolution." The inflammatory products, which at the height of the disease blocked the alveoli, become liquefied, and are removed partly by absorption and partly by expectoration. And the process of absorption depends on the integrity of the drainage system of the lung. The main factor in the drainage of the lung is the lymphatic



system, which terminates in the bronchial glands. But in a lung affected by anthracosis or silicosis this drainage system has already become impaired, by the interference with its normal channels caused by the presence of mineral particles and the chronic inflammation which these excite. The lymphatics and the bronchial glands cannot efficiently perform their normal drainage functions. And hence it is not unnatural that in such lungs resolution is interfered with and delayed. The pneumonic consolidation may persist and become chronic, the acute pneumonia runs on into a chronic pneumonia. I have seen a good many cases of this nature. Only the other day I saw a miner, J. B., 38 years of age, who had been a rock-drill miner for 8 years. Two months before he came under my observation he had an attack of acute pneumonia. He had not recovered satisfactorily from the attack; he still had cough and expectoration, and was short of breath. I found on examination definite evidences of old-standing silicosis, and I found also that there was still some consolidation of that area of the right lung which had been the seat of the pneumonia, with a good many fine moist sounds. I suspected a secondary tuberculosis, but bacteriological examination showed that the process was not tubercular but pneumococcal, and the pneumococci proved, on inoculation, to be pathogenic to rabbits.

That is the one point to which I wish to direct your attention. The second is this, that not only does one find this type of chronic pneumonia following a well-defined attack of acute pneumonia, but one also frequently meets with cases of miners' phthisis where there are localised areas of pulmonary catarrh, sometimes of considerable extent, which run a chronic course, and which clinically closely simulate the localised catarrh of early tuberculosis. Yet when the sputum is examined no tubercle bacilli are found while pneumococci are present. These catarrhal areas are often basal, but they may occur also in the upper lobes, or on the right side in the middle lobe. This indeed is one of the modes by which the disease commonly progresses. I could quote one or two cases of this sort which have recently come under my observation, and the idea that they were not tubercular but probably pneumococcal in nature is distinctly indicated, I think, not only by the absence of the tubercle bacillus from the sputum and the presence of the pneumococcus, but by the fact that several of them cleared up comparatively quickly under treatment. The conjunction is too frequent to be without significance. Indeed, the more one investigates the bacteriology of lung affections amongst the Rand miners, the more one is struck by the almost universal presence of the pneumococcus in the sputum. For example, of the last ten specimens of sputum from non-tubercular cases examined, pneumococci were found in eight, and in four cases where inoculation was practised the organism was found to be pathogenic to rabbits.

The conclusion one is led to, therefore, is that the super-vention of tuberculosis does not account for all the cases of the moist type of miners' phthisis which we meet with, but that other infective processes, and particularly subacute pneumococcal infections, may also be concerned in their causation, especially in those cases which run a less acute course. In many, no doubt, pyogenic organisms also co-operate.

#### THE INFLUENCE OF MINE GASES.

And now let me mention very briefly the third main causative factor, the influence of mine gases. That acute cases of "gassing" are usually due to carbon monoxide poisoning has always been recognised, and Dr. Pakes has recently found the characteristic spectroscopic appearances, indicative of the presence of carbon monoxide in the blood, in more than one fatal case. That cases of acute irritant pneumonia due to poisoning by nitrous fumes also, but much more rarely, occur is likewise known. These gases are produced from the nitroglycerine explosives which are used on the Rand, and the more imperfect the process of explosion is, the greater is the quantity of these noxious gases which is generated. From these facts it is not a far step to infer that a subacute or chronic carbon monoxide poisoning may be amongst the dangers to which our miners are under certain working conditions exposed, and for his vigorous insistence on this view credit is due to Mr. Heymann, who recently advanced somewhat strong opinions on this aspect of the Miners' Phthisis question before the Chemical and Metallurgical Society of South Africa. The analyses of mine gases "under normal working conditions" made under the direction of the Commission on Miners' Phthisis, which are published in their Report, and which show for "normal mine air" an average value in six samples of 0.13 per cent. of carbon monoxide, have given this supposition a basis of experimental evidence. One must question whether these samples are really to be regarded as *representative* values of "normal mine air under ordinary working conditions." They probably represent conditions which are exceptional, and one would like to see them repeated and extended before they form the basis of too much dogmatism. But, so far as the evidence at our disposal carries us, it certainly goes to show the existence of a serious degree of vitiation of the mine atmosphere, at all events in what we may call "dead ends," in the ends of rises, drives, and winzes, where ventilation is necessarily less efficient, and the evidence goes to show also that the amount of carbon monoxide present under these conditions may be sufficient to affect the health of the workers, and produce definite symptoms on its own account. Miners would call these "bad places." The recognised effects of chronic carbon monoxide poisoning are, in the general order of their appearance, headache, and neuralgic pains, progressive

anæmia, and breathlessness on exertion, degenerative inflammation of the nerves, and sometimes mental disturbances. The two latter I have not seen, but I agree that a miner working day after day in such a "bad place" would suffer probably from chronic carbon monoxide poisoning. As a matter of fact, it often happens that a miner tells you that, when he was working in a rise or an ill-ventilated drive continuously for three or six months, he felt during that time that he was out of sorts, that he was steadily getting weaker, less able to do his work, and more short of breath, until finally he stopped his work, or went to a better part of the mine. Then, he will tell you, he began to get better again. Such cases as this are not infrequent. Two months ago, for example, a rock-drill miner came to me. He was a young man, aged 25, and had worked rock-drills in Cornwall for 10 years, and for six months in South Africa. He had definite symptoms and signs of silicosis of the dry type and was also very anæmic and short of breath. He had worked for three months in a "gassy" drive, and his boys had been "gassed" several times. He had no tubercle bacilli in his sputum. I advised him to discontinue work for a time, and in a fortnight his anæmia had almost disappeared and he felt much better although the signs of silicosis of course remained. Now this apparently was a case in point, in which, superadded to a primary silicosis, there were marked anaemia and increased breathlessness, which were due to a chronic carbon monoxide poisoning. I have little doubt, then, that in such cases we may have what we may call a subacute or chronic carbon monoxide poisoning, of a degree sufficient to cause symptoms of itself, and certain to aggravate any pre-existing silicosis. It may be, indeed, that account must be taken of this factor, in explaining why miners' phthisis is more fatal here than in other mining centres. It is quite likely that some and even much of the anæmia from which miners suffer is traceable to this cause, and the general anæmia and lowered vitality also necessarily imply a local lowering of vitality on the part of the lung, rendering it more susceptible to the action of irritants and the invasion of infective processes. I agree, therefore, that the aggravation of miners' phthisis caused by mine gases may in particular cases be considerable and may even precipitate a fatal issue. But that carbon monoxide can of itself produce a fibrosis of the lungs *of the type which we find in these cases* I see no reason to believe, for, as I have stated, the intimate association of the process of fibrosis with the presence of mineral particles is in every case unmistakeable in the specimens which we have examined microscopically.

That nitrous fumes also are capable of producing and maintaining catarrhal changes in the air passages and alveoli we have always agreed, but the proportion of these which are actually present in the analysed samples of mine air is very

small, and hardly sufficient to lead us to regard this gas as important under ordinary conditions.

I do not propose in this paper to discuss the question of treatment. The "treatment" of miners' phthisis must be preventive. One can do something to ameliorate symptoms, and it is possible to promise to a patient, in whom the processes which I have described are not too far advanced, that, if he give up underground work altogether, the urgency of his symptoms, so far especially as they are due to catarrh or the influence of vitiated air, will be greatly ameliorated, and that he may enjoy many years of comparatively good health. But too often the warning and the promise fall on deaf ears. Our modern working man, our modern miner at all events, is like some of ourselves, very much a bundle of specialised habits, and beyond the narrow scope of these activities he has no outlook. Often, too, he may have wife and children depending on him, and rather than risk the chance of hardship, with health already impaired, which a break with his calling necessitates, he will choose the graver risk of a fatal persistence in it.

And therefore what we must aim at is prevention. A Commission is at present investigating the question of a possible improvement in the ventilation of our mines, which might mitigate the danger arising both from dust and gases, and a Committee appointed by the Chamber of Mines is engaged in investigating the question of what practical devices can be recommended for reducing the generation of dust in drilling and blasting operations. These devices mainly depend on the application of water, as atomiser, spray, jet, or water drill. To these bodies the mining community looks for practical advice to aid them in reducing the incidence of miners' phthisis, and in staying so far as may be the high mortality of which it has hitherto been the cause.

One point more in conclusion. Why, it may be asked, is miners' phthisis apparently more prevalent and more fatal on the Rand than in most other mining communities? I think that the main reasons are these:—First, that the rock is hard and the mines are dry; second, that the number of rock-drills used in the mines is proportionately great; and third, that the quantity of explosives used is also proportionately large.

#### EXPLANATION OF PLATES, IX.—XIII.

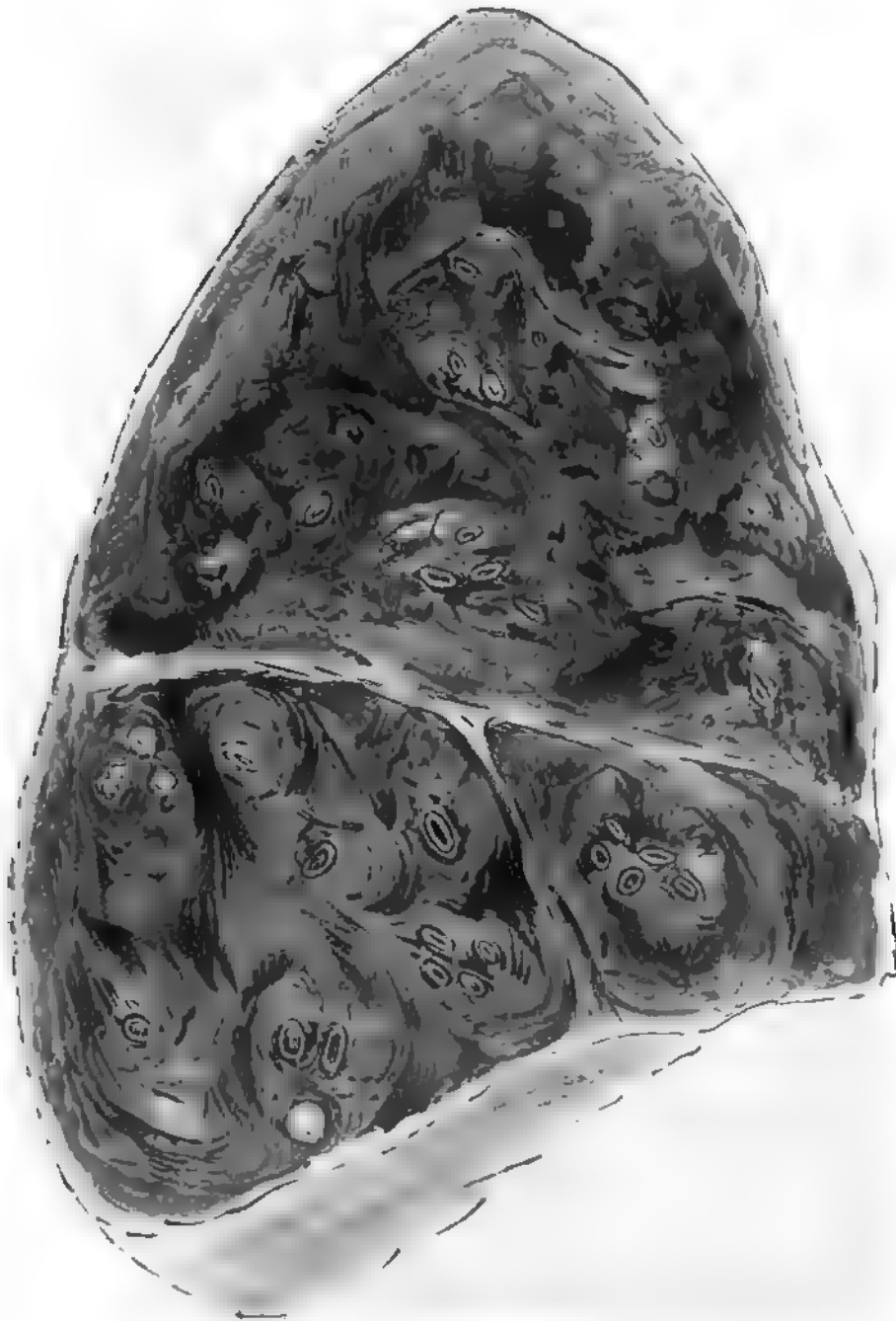
PLATE IX.—Right lung of T. W., miner, aged 52. The middle and lower lobes are fully consolidated.

PLATE X.—Right lung of W. P., Rock-drill miner, aged 34. Two large cavities are apparent one in the lower and one in the middle lobe.

PLATE XI.—Left lung of J. T., Rock-drill miner, aged 37. Very advanced fibrosis with cavity formation.

**PLATE XII.**—Microscopic appearances of commencing fibroid change in case of miner's phthisis (x 50). The section shows here and there pigmented particles in the walls of the air cells, and shows also the special tendency of these particles to accumulate round the blood vessels and bronchi, there giving rise to irritative changes and the development of new fibrous tissue. Some of the air cells are seen to be the seat of catarrh but many are normal. The aggregation of pigmented particles in one of the interlobular septa is also clearly shown. Specimen prepared by Dr. E. Hamilton.

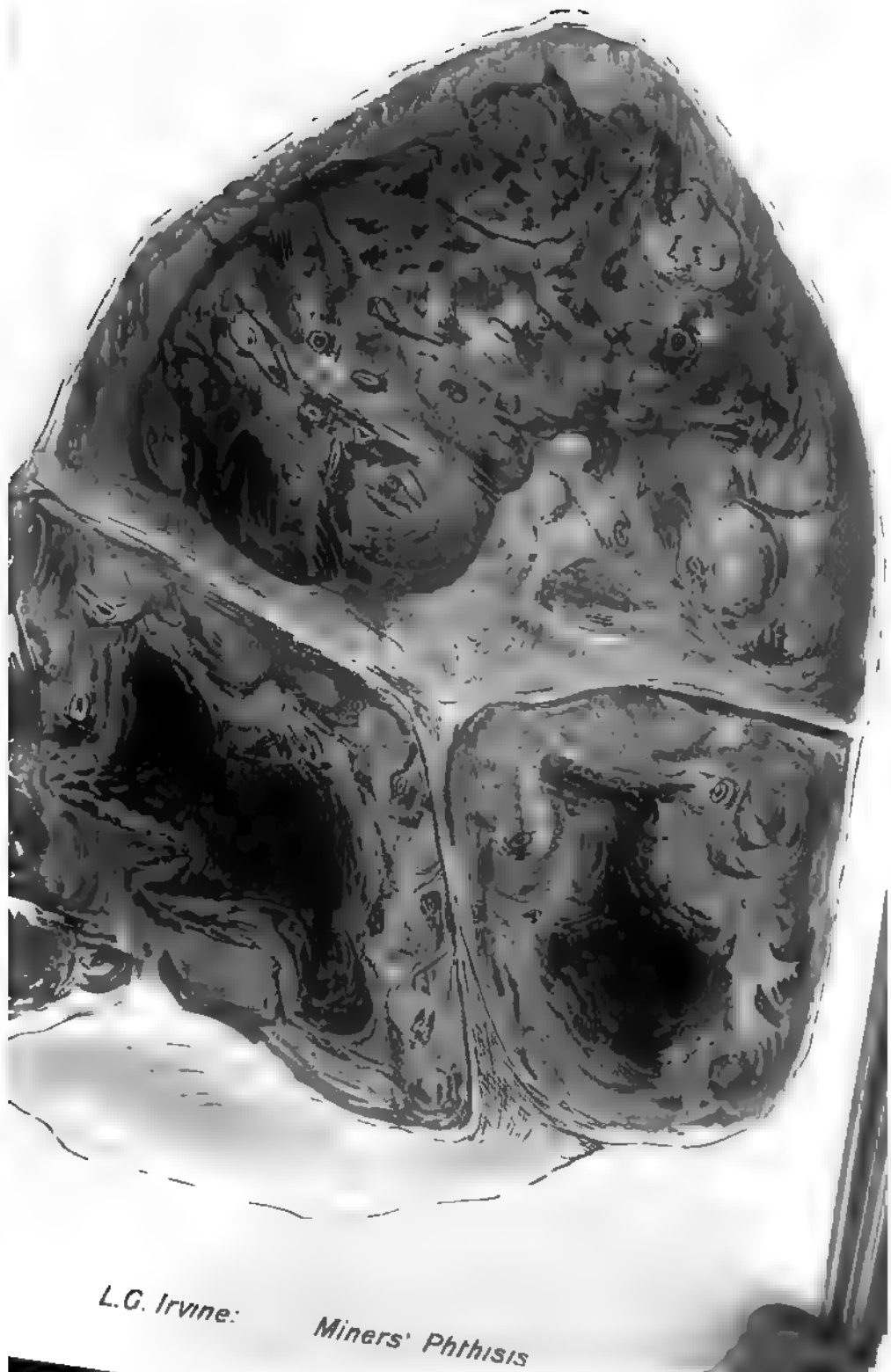
**PLATE XIII.**—Section from same lung as No. 5 in an area of more advanced fibrosis (x 50). The nodules here shown are just visible to the naked eye. The development of the fibroid change by the growth and coalescence of nodules is well seen. Six nodules are shown in the field: in the two largest the blood vessel or bronchus around which the fibroid change originally developed has disappeared, the others still show the blood vessel or bronchus in the centre of the discrete nodule. The surrounding air cells are in a condition of catarrhal inflammation and numerous pigmented particles can be seen in their walls. Specimen prepared by Dr. E. T. Hamilton.



L.G. Irvine

Miners' Phthisis





L.G. Irvine: *Miners' Phthisis*

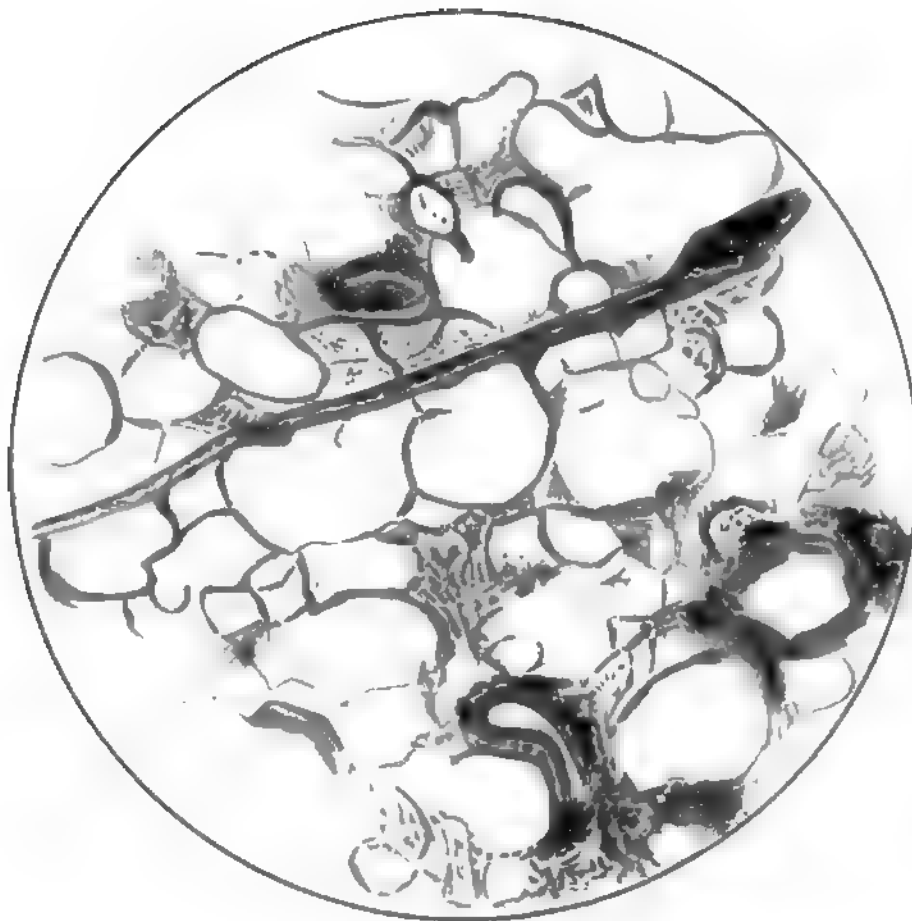






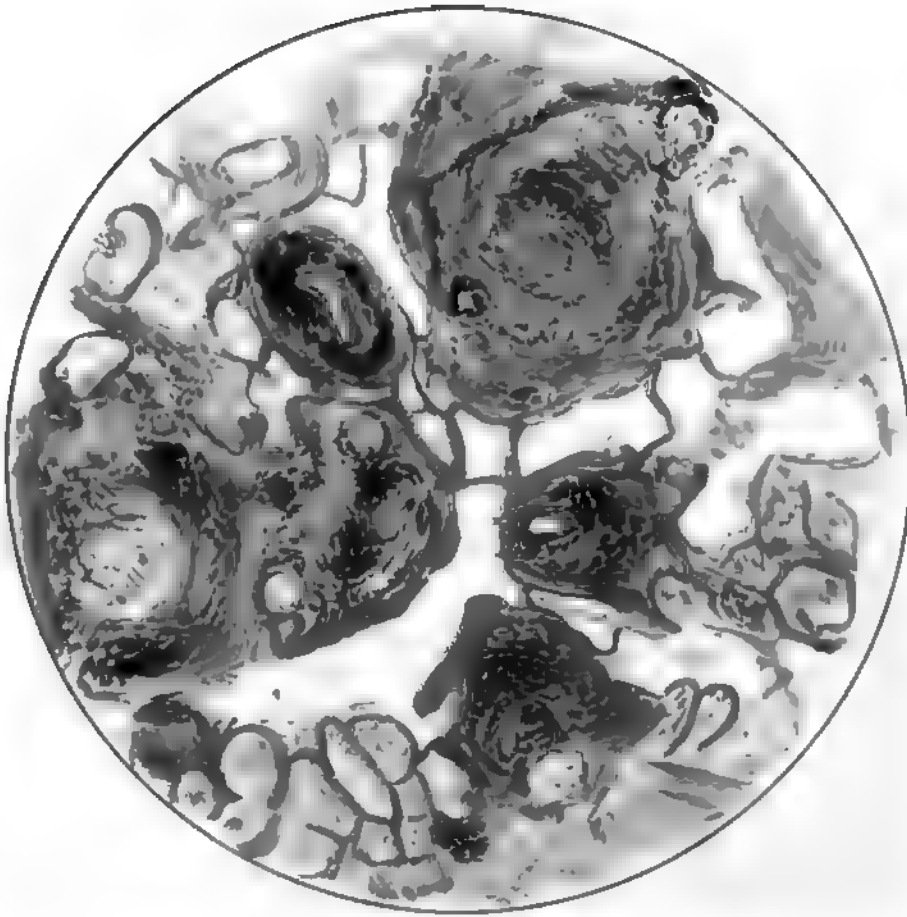
*L.G. Irvine: Miners Phthisis.*





*L.G. Irvine: Miners' Phthisis.*





*L.G. Irvine: Miners' Phthisis.*



## 17.—NOTES ON SOME PATHOGENIC BACTERIA AS FOUND IN THE TRANSVAAL, AND THE VARIATIONS FROM THEIR EUROPEAN PROTOTYPES.

By F. H. JOSEPH, ASSISTANT BACTERIOLOGIST, GOVERNMENT LABORATORIES.

Bacteriology in the Transvaal is, as yet, in its infancy. In 1898, Drs. Brodie, Rogers and Hamilton\* did some valuable investigation on the pneumococcus, and this appears to be the only work attempted prior to February, 1903. So that, what little knowledge we have of the science, in its application to the peculiar conditions of this country, has been practically all acquired during the last fifteen months. But this brief period has been sufficient to show that, not only is the bacterial flora of the Transvaal far different from that of Great Britain and the Continental countries, but that, owing possibly to climatic influences, many of the recognisable micro-organisms exhibit considerable modification from the European types.

It is the purpose of this paper to indicate briefly some of the more striking points of difference that I have observed with regard to the distribution, morphology, virulence, and cultivation of a few of the pathogenic bacteria.

### PNEUMOCOCCUS.

The Pneumococcus is the "causa causans" of pneumonia, and frequently of meningitis and other allied conditions.

These diseases are very prevalent among both the white and black populations of this Colony, and account for a considerable percentage of the annual death-rate.

Not only is the Pneumococcus exceedingly common in this country (being found in at least 70 per cent. of normal sputa), but it is present in a highly pathogenic form.

Drs. Eyre and Washbourn, of Guy's Hospital, London, in their paper on "The varieties and virulence of the Pneumococcus,"† state that they had exalted the virulence of a certain strain of Pneumococcus to such a degree that one-millionth part of a loopful (capacity of a loop about  $\frac{1}{2}$  milligram) of solid cultivation of this organism killed a rabbit in twelve hours.

In the Government Laboratories here, we have strains of the Pneumococcus, isolated from cases of pneumonia occurring in Johannesburg, which are of such virulence that *one ten-millionth* part of a loop (of approximately equal size to that of Eyre and Washbourn) invariably proves fatal to the animal in the stated time. Therefore it is reasonable to assume that the Pneumococcus of the Transvaal is at least ten times as virulent as the home types. Again, the virulence of an individual cultivation appears to be capable of being more quickly raised.

\* "Contributions to the Pathology and Infection of the Pneumococcus." Brodie, Rogers and Hamilton. *Lancet*, Oct. 22nd, 1898.

† "The Varieties and Virulence of the Pneumococcus." Eyre and Washbourn. *Lancet*, Jan. 7th, 1899.



Dr. Washbourn found that he had to pass his *Pneumococcus* through twelve or more rabbits, in order to attain his standard strength; whilst we have been able to reach our higher standard by means of but three or four passages.

This organism is certainly far more pleomorphic in this country, for diplococci are often seen that are four or five times the normal size. This peculiarity is noticeable, not only in pure cultivation, but it is even more strikingly shown in sputum. The streptococcus form is rarely met with here. A point of considerable importance with regard to the *Pneumococcus* of the Transvaal is, that it will grow in broth at a temperature as low as 20° Centigrade, even when it is still extremely virulent. A fair turbidity is observed in the medium at the end of 48 hours.

#### MENINGOCOCCUS.

The *Diplococcus intracellularis meningitidis* (or, as it is now usually called, the Meningococcus) was first found by Weichselbaum in the cerebro-spinal exudate in cases of basal meningitis. It has since been proved to have been the cause of some epidemics, as well as certain sporadic cases of this disease.

The organism, as described by Weichselbaum and others, grows well on the usual artificial media of the laboratory, when incubated at body temperature, but ceases to grow at 20 centigrade. Individual cultures die out very quickly, often in four or five days.

The Meningococcus isolated in the Transvaal from a case of undoubted meningitis, differs from the above description in many points.

It can be readily cultivated at 20° Centigrade.

The growth on the surface of gelatin becomes visible to the naked eye in from forty to forty-eight hours, and appears as minute, slightly raised, semi-translucent, white, closely-packed colonies, which do not coalesce until the culture is several weeks old.

In stab gelatin cultures, the growth closely resembles that of the streptococcus, but the colonies along the needle track are more delicate. The gelatine is not liquefied, nor are bubbles of gas produced in it.

Moreover, not only does this organism grow at 20° Centigrade, but I have successfully sub-cultivated after two and a-half months' continued growth at that temperature.

The other cultural reactions and morphology of this coccus appear to coincide with the usual descriptions.

#### BACILLUS COLI COMMUNIS.

The *Bacillus coli communis* has been found in many inflammatory conditions, chiefly in connection with the alimentary track and urinary system.

Under these conditions it frequently assumes considerable

pathogenic properties; growth in the tissues seems in some way to heighten its virulence. This organism is a normal inhabitant of human and animal intestines, and it is more on this account than because of its pathogenicity that it assumes so much importance. It is for this reason that its presence is used as an indicator of fæcal contamination in milk, ice-cream, and food-stuffs, but more especially in water.

The *Bacillus coli communis* is found in a great number of varieties, but the form that is generally recognised as typical, and which Dr. Pakes describes in his "Observations on the life history of the Bacillus Coli Communis,"\* has the following principal characteristics:—

On the surface of gelatin it gives a thin, semi-translucent growth, which has a very irregular, indented margin, and in three to five days spreads out almost to the walls of the test-tube.

Milk is coagulated, usually in forty-eight hours, when incubated at 37° C.

Dextrose and lactose are invariably fermented.

Sulphuretted hydrogen is evolved in from three to four days.

From observations of over seventy bacteria of the Coli group obtained in this country, and chiefly from water, I have found that the most common type varies fairly considerably from the aforementioned standard.

In gelatin cultures, the growth is more raised and opaque, and spreads out but little on the surface, while the margin of the colony is only slightly wavy, or frequently quite regular.

Milk takes longer to clot, usually five or six days is necessary. The reaction is rarely observed in forty-eight hours.

Dextrose and lactose are always fermented, as above.

Sulphuretted hydrogen is produced somewhat earlier, usually in from two to three days, but traces are often apparent in 24 hours.

Motility is always observed, and appears on the whole to be somewhat more marked.

This latter point differentiates the organism from the *Bacillus lactis aerogenes*, with which it might otherwise be confounded.

#### B. PYOCYANEUS.

The *Bacillus pyocyaneus* has been found in connection with various lesions in the human subject; and Symes has stated that it may be pathogenic to man. It gives the peculiar tint to green pus, and is frequently present in discharge from wounds. It has also been described in diarrhoea, and also in some gastric diseases of children.

The bacillus as found in this country conforms almost entirely to the usual text-book descriptions. Practically the only

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\* "Observations on the Life History of the Bacillus Coli Communis." Pakes. Transactions of the Pathological Society of London, Vol. 52, Pt. II., 1901.

difference I have observed in its cultural reactions is that, whereas the European *Pyocyaneus* produces a slight acid reaction in both lactose and saccharose broths, the Transvaal strain invariably renders these media strongly alkaline. Its growth on other media, pathogenicity and property to produce pyocyanin, are all identical. The chief point of interest to us concerning this organism is the comparative frequency with which it is present in our water supplies.

In the British Isles this bacillus is a very uncommon inhabitant of drinking water.

Dr. W. C. Pakes has made several thousand bacteriological examinations of water, collected from all parts of Great Britain, but has isolated it only twice; yet, I have found the typical *Pyocyaneus* on no less than six occasions, out of a total of only 450 waters, collected from different sources in the Transvaal. We have not yet been able to determine the cause of this phenomenon, but in each case the number of other bacteria has been excessive, and the water has been bacteriologically condemned.

#### BACILLUS PESTIS.

The outbreak of plague in our midst is sufficient cause to warrant a few brief remarks on this organism.

The *B. pestis* is the prime cause of plague in its three forms—bubonic, septicaemic, and pneumonic.

As you are aware, it is the latter type which at present prevails in Johannesburg and district.

There have already been a few bubonic cases, and it is probable as the plague diminishes in virulence the pneumonic variety will gradually give place to the bubonic.

A noticeable fact in connection with this epidemic has been the extreme rapidity of the progress of the disease. In most of the earlier cases, the onset of the symptoms had a fatal termination in less than 48 hours, and frequently in 24 hours.

The characteristic bacilli are often present in the sputum, or even in the saliva of living cases. After death microscopical examination of the lung juice reveals large numbers of the bacilli; the blood usually contains them in small numbers, as also the spleen and other organs.

In the lung, the plague organism is often found associated with the *Pneumococcus*, and it is on this account, as well as the similarity of the symptoms and "post-mortem" appearances, that pneumonic cases of plague are sometimes recorded as ordinary rapid pneumonias; and it is not until the bubonic form appears that their true character is known.

The *Bacillus pestis* isolated during the present outbreak is, as one would expect, one of highly virulent type. Guinea-pigs inoculated intraperitoneally with a pure culture of the organism die in from 24 to 48 hours.

On one or two occasions injection of half a c.c. of sputum,



L.G. Irvine:      *Miners Phthisis.*

## 18.—THE SCIENCE OF BACTERIOLOGY AND ITS COMMERCIAL ASPECTS.

By W. H. JOLLYMAN, F.I.C., F.C.S., ETC.

It is not my intention this morning to weary you with a long technical description of the methods of bacteriological investigation, but I think it advisable to mention the chief characteristics of bacteria, and to give some idea of the means adopted for their isolation and identification.

Bacteria are single-celled organisms occupying a position near the bottom of the scale of living things, and, being unicellular, their structure is of the simplest nature, consisting of a cell-wall containing protoplasm.

Dividing bacteria into two general classes according to their shape, we have bacilli—which are rod-shaped—and cocci, these are spherical.

The method of reproduction is probably asexual, a mature organism simply divides into two complete cells, and as this division may take place every twenty minutes one can appreciate that in 24 hours a single bacillus would have a family of hundreds of millions.

A single bacterium is so small (about 1-20,000 of an inch in length) that it can only be seen under the highest powers of our microscopes, but when very large numbers develop in one spot their presence may become evident to the unaided eye.

As occurring in nature, bacteria may be divided into two groups—the parasitic and the saprophytic—but members of the former class do not always require a living host, and some of the latter may at times become parasitic.

The disease-producing organisms are chiefly found in the parasitic group, but many members of this class have normally no pathogenic properties.

The identification of any bacterium is accomplished: (1) By its microscopical appearance, and power of locomotion when in a suitable fluid medium; (2) by its affinity for certain aniline dyes; and (3) by the character and chemical reactions of its growth upon culture media. The culture media have usually, as a basis, a watery extract of meat, to which various chemicals may be added, and which may be solidified by the addition of gelatin or agar-agar (Japanese sea moss).

Other media, such as milk, slices of potato, bread, wort, beer, eggs, solidified blood serum, etc., are also used. To determine the causal relationship of any bacterium to a given disease, it is necessary to isolate the organism from the body, and to reproduce the symptoms, or induce death by inoculation of the culture into some animal. As, however, in some cases human diseases are not communicable to animals, we have to assume from the constant presence of the organism in the part of the body affected that it is really the cause of the condition observed. Of the parasitic bacteria which are not usually associated with any disease there is a large number, and the

rôle they play is not always easy to determine; they may be of use, or they may be merely adventitious. Of the non-pathogenic bacteria, we can safely say that many are of the greatest value to humanity, in that they are the ultimate factors bringing about the complete decomposition of the waste and injurious products of the animal organism. That some members of the saprophytic group determine the fertility of a soil is a fact, the importance of which cannot be denied, and nowadays many commercial processes are based upon our knowledge of the bacteria which bring about desired changes in organic substances, but this subject will be dealt with at greater length later on. You may perhaps say, "The science of bacteriology may be very interesting, but what practical results accrue from its study?" The object of this paper is largely to answer that question, and I will divide my reply into four sections, showing:--

(1.) The assistance the science renders to medicine in the matter of diagnosis of disease.

(2.) The improved treatment and consequent lessened mortality resulting from a knowledge of the causal agents.

(3.) The public health and sanitary science aspects of the study.

(4.) The work bacteria do in other than medical fields.

1. More rapid diagnosis may be made with the aid of bacteriology in the majority of cases of diphtheria, tuberculosis, pneumonia, plague, enteric fever, influenza, cholera, puerperal fever, anthrax, and glanders in the human subject, and in the case of animals especial mention should be made of tuberculosis and glanders. It may be of interest to mention how the bacteriological diagnosis is made in some of the above cases.

Take diphtheria, for instance. A child complains of a sore throat, some of the exudate from the fauces is examined microscopically, and by culture in suitable media. Within 12 hours, and frequently within 30 minutes, the bacteriologist has his result, which, if positive, is quite definite, and if negative--well, there is only a small chance of error, and as in the subsequent treatment of the case, the life of the child often depends upon an early diagnosis, the value of that bacteriological examination is obvious.

Tubercle bacilli are very often found in the expectoration of tuberculous patients long before a certain clinical diagnosis could be made, and here again the value of an early diagnosis, followed by suitable treatment, is so well known that there need be no more said on this point. In puerperal fever, pneumonia, etc., the bacteriological examination is often attended with great benefit to the patient.

Before discussing plague, I should like to mention that this paper was commenced some weeks before the presence of plague in Johannesburg was discovered. However, at the present time I see no reason for altering my opinions as put down

in January. At that time I wrote: "This disease is of special interest to the dwellers in all sub-tropical countries, so I shall make no apology for giving a somewhat lengthened description of the methods of diagnosis and prevention. So far this country has been free from plague, and that it may long remain so is the earnest wish of all, and I am in a position to assure you that, should this dreaded disease appear, it will never gain a foothold, provided the inhabitants co-operate with the medical officers in carrying out all necessary preventive measures."

As is well known, plague is largely, if not entirely, carried from an infected area to a new district by rats. Obviously, therefore, we should subject every rat found dead to a careful bacteriological examination. The result is obtained very rapidly, and should be followed, if a positive diagnosis is given, by a crusade against all the rats in the district. Before the appearance of most plague epidemics of recent years, large numbers of dead rats have been discovered. The present outbreak has been remarkable in that the authorities had no forewarning in the shape of plague-stricken rats previous to the outbreak. Had these dead rats appeared, preventive measures would have been adopted in the case of every person who had been liable to infection. The disease itself may be diagnosed bacteriologically at a very early stage, so you will see that being forewarned we are also forearmed. But time is short, and I must proceed to the second section of my reply. The beneficial results of an early diagnosis are obvious, and bacteriology has given us, in many cases, specific cures for those diseases which are caused by bacteria. I refer to the antitoxins and therapeutic sera. Perhaps the reasoning which led bacteriologists to think that these sera might be of service and the methods of their preparation are not popularly known, so a short description may not be out of place. In a case of typhoid fever, it has been found that, after a few days' illness, the patient's blood has a marked and very characteristic action upon typhoid bacilli grown in artificial media. As this action appears to be an inimical one, it might be thought that the organisms causing the disease had produced in the blood some substance antagonistic to the causal bacteria. That a similar state of affairs exists in artificial cultures we have abundant evidence. In view of these facts it was supposed that the blood from diseased people might have a beneficial effect upon the course of the same disease in another patient; but, as human blood is not usually available, recourse had to be made to animal experiment, and, speaking generally, the procedure is as follows:—An animal which is susceptible to the disease is inoculated with a dose of bacteria, which has been found experimentally to be too small to cause death. Probably for a time the animal will fall sick, but soon recovers; a larger dose is then administered, for it is found that the animal is now not so susceptible to the disease as at first; and so gradually in-



creasing doses are injected until it becomes practically impossible to kill the animal, even though the final dose may be more than a million times as much as would have killed it at first. Having now made the animal immune, its blood is found to have a marked disinfectant action (either bactericidal, i.e., it actually kills the invading bacteria, or antitoxic, neutralising the poisonous substances produced in the body).

A quantity of blood is now drawn from the body of the experimental animal; this is allowed to clot, and the clear fluid separating is carefully preserved, and forms our antitoxin or serum. There are other methods by which bacterial remedies are prepared, some of which do not necessitate the use of animals, but the most effective agents are prepared from blood.

The bacterial sera may occasionally be used as preventive vaccines, but their action is generally curative only.

A few words on the observed results of the use of some of these sera.

In the case of diphtheria antitoxin, the beneficial effect of its injection into diphtheritic patients will readily be seen when I say that in 1891 in London 22.5 per cent. of the cases of diphtheria were attended with fatal results, and in 1901, although diphtheria had been greatly on the increase, only 11 per cent. of the patients died; the great decrease in the death-rate being due solely to the fact that bacteriology permitted of an earlier and more definite diagnosis than clinical methods, and that the study of this science had given the medical profession a therapeutic agent of far greater value than had been possessed before.

A very large number of experiments have been carried out with plague sera in India, and while these results have not been confirmed in other plague epidemics, I will quote one statement relative to the value of the use of prophylactic inoculation. Captain Leiman, of the I.M.S., stated that he had performed over 80,000 inoculations, with a resulting decrease of 90 per cent. in the number of persons attacked. (In the case of the Johannesburg epidemic, it must be remembered that the plague has assumed the most deadly form—the pneumonic—and Captain Leiman's experience was gained when working with the bubonic type.)

Pneumonia is a disease which, in this country, is as deadly as tuberculosis in England, and at the present time little can be done to check its ravages. However, there are good grounds for hope, and I may say that there is sufficient evidence that before long the death-rate from pneumonia in South Africa will be very materially reduced. In England the disease has been studied, and our knowledge greatly advanced, by the late Dr. Washbourn and Dr. Eyre. These workers paved the way for future bacteriologists, and have, by their researches, largely increased the possibility of production of an anti-pneumococcic serum. At the present time, however, the most valuable serum



is produced in Italy by Professor Pane. It is too early in the history of this remedy to offer any statistical evidence of its value upon the human subject, but large numbers of animal experiments have proved that it is capable of saving life when no other known remedy would have availed.

I have done little more than state dogmatically that the bacterial sera possess a very great therapeutic value, but I trust the facts placed before you are sufficient to justify one in hoping that further work in this important branch of the science will result in a general decrease in the mortality from the many diseases of bacterial origin.

In my third section I propose to deal shortly with the methods adopted for the prevention of epidemics. The early detection of the presence of plague by examination of rats, and some of the preventive measures to be adopted, are already discussed.

Typhoid is a disease which practically only assumes epidemic form when the water supply of a district becomes specifically infected. It is by no means an easy matter to demonstrate the presence of typhoid bacilli in water, and indeed this has only been done on a few occasions. This being so, it may be urged that the bacteriological examination is unnecessary, for the delicate chemical methods at the disposal of an analyst will show contamination.

But chemistry does not go far enough. Bacteriology not only shows contamination, which may be so slight as to have escaped detection by chemical methods, but it also demonstrates the origin of that contamination.

It is not my intention to discuss further the relative values of the chemical and bacteriological examination of water, for time is short, and I wish to place before you established facts.

It has been stated that the bacillus of typhoid fever is seldom isolated from drinking water, but organisms which must come from the intestines of some animal or man are found in the sewage-contaminated water, and are absent from unpolluted supplies, hence the bacteriologist feels justified in condemning as unsafe any sample of water containing these intestinal organisms, for though at the time of examination no typhoid bacilli are found, who can say when they may not infect such a water, and it is better to lock your stable door always than risk losing your horse by insufficient care.

In the Maidstone epidemic in England in 1897-98 there is absolutely no question that if the town's water supply had been periodically and frequently examined, the epidemic would have been prevented.

To pass to another disease, communicated largely by polluted water, fortunately not epidemic in this country—cholera.

During the great cholera epidemic in Hamburg (Altona) it was proved beyond question that the disease was due to infected water, for in one street it happened that the houses on

one side were supplied with the polluted water, and the inhabitants were decimated by the disease; the other side of the street had a pure supply, and the inhabitants were free from cholera. This occurred in the infancy of bacteriology, when Koch was making some of those remarkable discoveries which set bacteriology on a sound basis; such a state of affairs could not exist nowadays if the water supplies were carefully examined.

It is impossible to go into the question of investigation of milk for diphtheria, etc., or the means adopted for stopping outbreaks of the disease in schools by careful examination of the throats of all subject to contagion, but the work is being repeatedly undertaken in England and elsewhere with most satisfactory results.

The subject of public health would not be complete unless some reference was made to sewage disposal.

This matter is easily dealt with in the case of towns situated by the sea or tidal river, the sewage being conveyed by pipes to a suitable distance from the shore, and being discharged on the ebb tide. This is simple, and in some cases satisfactory; that it is not always safe has been proved by the typhoid epidemic two years ago in England, when the disease was unquestionably spread by oysters from sewage-contaminated beds. Moreover, a mixed sewage has a high manurial value, and why should thousands of pounds worth of good crop-producing matter be thrown into the sea?

In inland towns the question is more difficult of solution; that rivers flowing near large towns should not receive sewage admits of no contradiction. What is to be done?

What has hitherto been done has depended largely upon local circumstance. If there is ample land to be easily obtained in the neighbourhood, the sewage has been passed on to it, the land has been farmed with, in many cases, very satisfactory results. For some years past experiments on small and large scales have been carried out to endeavour to determine if it is possible to make use of Nature's own method of getting rid of effete matter, and also if that method is capable of improvement. The bacteriological purification of sewage is largely practised at home, resulting in an enormous saving of time, land, and labour. I will give a very few words on the method, but I trust they will suffice to show that the scientific method is an improvement upon the older farming process.

The decomposition of sewage is effected by allowing the bacteria normally in the sewage to act upon it in fairly deep tanks filled with coke.

The first part of the process takes place in the absence of air, the sewage is then allowed to pass into another tank where the air has easy access, and after this, if the fluid is allowed to undergo still further purification in the presence of air, the resulting effluent is clear, inoffensive, will not undergo further decomposition, and may be used, if possible, for agricultural purposes.

What has happened is this: sewage contains a large quantity of organic nitrogenous matter; this is, by the first purification, largely resolved into simpler substances, among which ammonia is one of the chief; the second completes the work. In the presence of excess of air, the bacteria produce from the ammonia compounds the nitrates which are essential to the growth of most plants.

Now to run over some of the non-medical results of bacteriology.

Here I might profitably refer back to some of the work of one of the founders of modern bacteriology—Pasteur.

Some of his earliest work was directed towards discovering the cause of bee and silkworm diseases, then to investigations into the fermentation problems of wine and beer-making, and no one who has had any experience in modern brewing will deny that the results achieved nowadays are infinitely better than those of thirty years ago, bacteriology having shown, not only the germ cause of bad results in brewing, but also how to prevent the souring of alcoholic fluids, and more, how to improve the fermented liquor by inoculation of the mashes with suitable yeasts.

Time will not permit of much more than passing reference to many of the uses of bacteria in the trades, but I should like to make special mention of some of the lesser known processes.

Vinegar and cider-making I will pass over. The influence of bacteria on butter is great, and the discovery of the cause of the souring of butter has led to improved methods of manufacture. Butter fat alone is not a good nidus for bacteria, but when mixed with water and some nitrogenous substance it is readily turned rancid. Without the nitrogenous material the bacteria cannot develop, so butter which is intended to keep in good condition for any length of time should be as free as possible from curd. This fact has led to the introduction of improved forms of separators, with correspondingly satisfactory results.

The ripening of cheese is entirely a bacterial process, and a study of the many organisms taking part will doubtless lead to the production of a more reliable article. The knowledge of the agents bringing about the souring of milk has resulted in methods being devised for sterilising the fluid in such a way that, without any added antiseptic, milk may be kept in perfectly good condition for an unlimited time.

From milk and milk products we will turn our attention to an industry which might easily become one of great importance to the Transvaal—tobacco curing. Experts tell us that this country is able to produce a really good quality tobacco, but so far the manufactured article cannot compete outside the country with the American varieties.

The quality of tobacco depends first upon certain flavouring substances produced by the growing plant, and secondly upon the changes resulting from the bacterial fermentations set up by the curing processes.

Hitherto this curing process has been carried out by rule of thumb methods, as was the case in brewing operations a few years ago, but experiments carried out by various investigators upon the advantages of curing by special cultures of bacteria obtained from well-known brands of excellent tobacco gives rise to the hope that a scientific investigation into this subject may result in as great an improvement in the tobacco produced in this country as has been noted in the case of fermented liquors at home.

While discussing the subject of plant fibres, I may refer to the preparation of good silos, again a bacterial process. There is no question that here again science may come to the aid of the practical man, and the study of the bacteria taking part in the production of sweet and sour fodder and brown hay has already resulted in improved methods for the preparation of these animal foods, and further investigations will doubtless lead to a still further improvement in the quality of the fermented material.

It is impossible for me to enter into the many other commercial processes, in which the chief agents are bacteria.

The influence of various bacteria in the sugar industry, in tanning, in the conversion of rice into alcoholic liquors, as practised in Japan, in the production of a large number of chemicals of great importance in some industries, may not be well known, but is nevertheless of vital importance to those industries.

There is one other branch of non-medical bacteriology which must be referred to—viz., soil bacteriology.

Plants of all kinds require for their development various chemical elements and complexes; amongst these, nitrogen, in the form of nitrate, is indispensable to the majority. In a virgin soil removed from luxuriant vegetation—say a patch of bare veld—it is found that nitrates are absent; if, however, this soil is treated with stable manure, everybody knows that it will soon become fertile. Why?

Manure does not contain nitrates, but it does contain plenty of nitrogenous matter, and this by the action of certain bacteria is converted into the nitrate required by plants.

The organisms observed in this change are very remarkable, in that they refuse to grow upon ordinary artificial media, and it is only through the researches of Winogradsky, Warington, and Frankland, who elaborated a solid medium similar in appearance to agar, but having as its gelatinising constituent, colloidal silica, that the present day we are able to isolate and study these interesting and useful bacteria.

The conversion of inert nitrogenous organic matter into valuable manurial nitrate takes place in several steps. The putrefactive bacteria always present in manure, etc., convert the nitrogen compounds into ammonia salts, then the soil organisms start. One group converts the ammonia into nitrous

acid, the acid formed being fixed by the lime in the soil, and then, finally, another class starts, and completes the oxidation of the nitrite into nitrate, this substance being in the form required for the nutrition of the plant.

I have said that nitrate is required by the majority of plants; the minority require nitrogen, but are able to utilise this element in the uncombined state as it occurs in the atmosphere. Here again, however, it is largely through the instrumentality of bacteria that this is possible. The nodules found about the roots of the various members of the leguminosae contain the organisms which fix the atmospheric nitrogen, and pass it on to the plant.

I have got to the end of my little attempt to give some idea of the influence bacteria have over our daily lives, from the scientific standpoint, and I must now justify the title of my paper.

To give statistics showing in £.s.d. what bacteriology saves the community is impossible. I can only run over some of the chief items on the credit side of the account, and leave their exact values to your imagination.

A human life is worth something to the community, and if, as a result of bacteriological investigation human lives may be saved—well, I think bacteriology will have justified itself.

The recent plague epidemic is testimony to the value of bacteriological work; what might have happened had not the early cases been examined bacteriologically one cannot tell, but it is quite certain that the money value of an early diagnosis has been incalculable.

With regard to the non-pathological side of the question the remarks made about brewing, butter-making, sewage disposal, soil fertility, etc., will suffice to indicate the commercial value of scientific investigation into these branches. What is going to happen in the future as the result of study of bacteriology it is impossible to foretell. On the medical side men are endeavouring to find out more about the causes of human diseases, and to follow up these discoveries by the introduction of specific cures.

Veterinary bacteriologists are doing the same work for animals.

In what may be called the bacteriology of the trades there is no question that there is a great deal to be done: brewing, tobacco-curing, manufacture of organic chemicals, possibly glycerine, and soap manufacture may before long become bacterial work, and so on.

Science is perennially supplying us with startling discoveries, but I think those of bacteriology can scarcely be surpassed.

The fact that the major portion of human disease is caused by bacteria of such infinitesimal size, is certainly somewhat terrifying, as it seems so impossible to control or modify in any

way, the action of such organisms; but one of the aims of science appears to be to achieve the impossible, and now we have many bacteria so completely under command, that instead of being enemies, they can be made to do work that is invaluable to the welfare of our kind.

## 19.—ALIEN PLANTS SPONTANEOUS IN THE TRANSVAAL.

BY JOSEPH BURTT DAVY, F.L.S., F.R.G.S.

### SUMMARY.

Definition of the term, "Spontaneous Alien Plant."

Classified and Annotated List of Species.

Numerical distribution among genera and families.

Relative Abundance of the Different Species.

Colonists.

Adventives.

Common Species.

Abundant Species.

Economic Aspect of the Subject.

Noxious Weeds.

Troublesome Weeds.

Innocuous Weeds.

Useful Weeds and Other Aliens.

Geographical Distribution.

Factors Governing Plant Migration.

The Origin of our Aliens.

Routes of Travel.

How Plants may Migrate.

### DEFINITION.

The phrase "alien plants spontaneous in the Transvaal" refers to all non-indigenous plants growing in the Transvaal which are known, or believed, to have made their first appearance in the country within historic times, and which grow spontaneously, that is, without having been artificially planted or cultivated.

It has been found necessary to a clear presentation of the subject, to include a few species which are native to South Africa, but which are either adventive on the High Veldt of the Transvaal, or are spreading as weeds on roadsides, vacant erven, or cultivated lands, and are thus becoming weeds.

Most, but not all, of the troublesome weeds of farm and garden, e.g., Burr-weed and Black-jack, are aliens. But not all aliens become weeds; for instance, *Cosmos*, the African Marigold and the Evening Primrose, are aliens, and have become naturalised, being spontaneous in several places in the Transvaal, but they are not weeds.

What, then, are weeds? Bailey's English Dictionary (17th Edition, 1757) defines a weed as "any rank or wild herb that grows of itself." Our ideas of weeds have, however, become specialised, and more definite, with increased knowledge of Botany, Horticulture and Agriculture, and a more modern definition of a weed is, "a plant growing out of place." Even this is incomplete, and we should prefer to say that a weed is *any plant growing spontaneously where it is not wanted*.



## CLASSIFIED AND ANNOTATED LIST OF SPECIES.

One hundred and forty-one (141) species and varieties of alien plants spontaneous in the Transvaal have been collected by the writer during the past year. The list may be considered fairly complete as regards the common weeds of the Boschveld and Hoogveld. It is not likely to be a complete list of alien plants of the Transvaal, however, as I have not had opportunity to visit the Low Country in the summer. It is probable that several aliens not enumerated here are to be found in and around Barberton, Komatiepoort, Leydsdorp, Hænertsburg, Pietersburg, Rustenburg and Zeerust. Even on the Hoogveld, almost every trek reveals one or two additional species, sometimes only a solitary individual of each, introduced probably during or since the late war, with military or repatriation forage or seeds.

In the preparation of the following list the writer has uniformly adopted the plan of decapitalising specific names, excepting only personal names in the genitive case. The use of the abbreviation "var." between specific and varietal names has also been dropped. The termination *aceæ* has been adopted for all family names, except in the case of the five families, Compositæ, Cruciferæ, Gramineæ, Labiatæ, and Leguminosæ; there does not appear to be any valid reason for changing these well-known names. Collections made near Fourteen Streams, about four miles west of the Transvaal western boundary, are included here, as showing the westerly extension of range of the species, and a suggestion as to a possible source of introduction of some of them.

The writer regrets that he had not access to a copy of Thunberg's *Flora Capensis*, in order to cite that author's early references to the occurrence of some of our aliens at the Cape. The references given in the *Flora Capensis* of Harvey and Sonder are only cited in part, owing to illness which prevented the completion of this paper before it was necessary to send it to press.

## Family AIZOACEÆ: Hottentot-fig Family.

*Limcum linifolium*, Fenzl. Monogr. in Ann. Wien. Mus. I.: 342 (1836). Native of tropical Africa; Senegambia, Lower Guinea (Angola, etc.) and the Mozambique district (the Zambesi); it has also been found south of the Transvaal (Caledon River, *Burke*). Zeerust, a common weed in cultivated ground at Willow Park Farm, May 21, 1903, *Davy* 95; Fourteen Streams, a garden weed, Feb. 14, 1904, *Davy* 1598.

## Family AMARANTACEÆ: Pigweed Family.

*Alternanthera* sp. Pretoria, on gravelly roadsides at Claremont, June 1, 1903, *Davy* 234; Fourteen Streams, a common weed, Feb. 14, 1904, *Davy* 1550. *A. sessilis* occurs as a weed in Natal, but the Transvaal plant differs from all specimens of *A. sessilis* and *A. nodiflora* in the Natal Government Herbarium,



and Dr. Bolus has not succeeded in matching it in his collection. It has the appearance of an alien. The bracts become stiff and prickly in age, and are unpleasant to the touch of bare hands and feet.

*Amarantus paniculatus*, Linn. Sp. Pl. ed. 2, 1406. **PIGWEED**, Mist-breed, Taape, Brèdes malabares. Native of tropical America; cultivated throughout India and Ceylon and up to 9,000 ft. alt. in the Himalaya, for the sake of its seeds, which are eaten by the natives. In Africa and East and West Asia it occurs in cultivation or as an escape, *Hooker*. An alien in Natal from 3,000 to 4,000 ft. alt., *J. Medley Wood*. Transvaal: Probably the most abundant weed of farm and garden, in the Transvaal; common in neglected gardens, around cattle kraals, on manure heaps, etc. The young tender leaves are boiled and eaten as spinach by natives and whites; a favourite forage plant of horses, mules, pigs, fowls, ducks, etc. Wild birds appear to be fond of the seeds. The stems are green in young plants, but become red with age. Pretoria, alt. 4,400 ft., a common weed, Jan. 4, 1904, *Davy* 885; Belfast (farm Rietvlei, alt. 6,000 ft.), the most abundant weed of field and garden, Feb. 5, 1904, *Davy* 1258; Standerton, a garden weed, farm Benginsel, March 30, 1904, *Davy* 1805; Haaman's Kraal R.R. Station (alt. 3,389 ft.), a ballast weed, Jan. 30, 1904, *Davy* 1097. Christiana (alt. cir. 4,100 ft.), a common garden weed, Feb. 16, 1904, *Davy* 1620.

*Amarantus spinosus*, Linn. Sp. Pl. 991 (1753). **THORNY PIGWEED**, Thorny amaranth, Brèdes malabares à piquans. Native of tropical America, naturalised elsewhere; a common weed around Durban. Transvaal:—A common weed on roadsides and vacant erven. Pretoria (alt. 4,400 ft.), a common roadside weed, Jan. 28, 1904, *Davy* 1072; Waterval Boven (alt. 4,800 ft.), a common weed, Feb. 4, 1904, *Davy* 1458; Barberton, a troublesome weed in cultivated ground, June 10, 1903, *Davy* 300; specimens have also been received from a correspondent at Spelonken. This species appears to start growth later and to flower later than *A. paniculatus*, L.

*Amarantus Thunbergii*, Moq. in DC. Prodr. **13**: pt. 2; 262. **CAPE PIGWEED**. Considered to be a native of South Africa, but having all the aspect of an alien to the Transvaal, where it occurs in farm-yards, on manure heaps, and on village roadsides. Pretoria, alt. 4,400 ft., a common roadside weed, 1904, *Davy*; Schweizer Reneke, common farm-yard weed at Vierfontein, Feb., 1904, *Davy*.

*Celosia cristata*, Linn. Sp. Pl. 205 (1753). **COCKSCOMB**. A tropical cosmopolite, occurring as an occasional and semi-spontaneous garden escape in the Transvaal. Pretoria, alt. 4,400 ft., a garden escape in town gardens and at Skinner's Court, March 26, 1904, *Davy*.

*Cyathula globulifera* (Bojer) Moq. in DC. Prodr. **13**: pt. 2: 329. Native of Abyssinia, Madagascar and parts of South

Africa, *Schinz*; occurs in Natal between sea-level and 2,000 ft. alt., *J. M. Wood*. Possibly indigenous in the Transvaal: Irene, alt. 4,803 ft., Nov. 1, 1903, *Davy*. Johannesburg, Bezuidenhout Valley, April, 1904, *Davy*.

*Gomphrena globosa*, Linn. Sp. Pl. 224 (1753). A common tropical weed, of uncertain origin. A common roadside weed around Durban, June, 1904, *Davy*. Evidently an alien in the Transvaal, where it is a common roadside weed: Pretoria, April, 1904. Our plant agrees with that at Durban, which has been named at Kew as above.

Family AMARYLLIDACEÆ: Narcissus Family.

*Agave americana*, Linn. Sp. Pl. 323. AMERICAN ALOE. Native of tropical America. Largely grown in the Transvaal as an ornamental plant, and for hedges around orchards and gardens and even at Kaffir kraals. Often semi-spontaneous on the sites of old farmsteads and Kaffir kraals. I am not aware that it has yet become spontaneous in the bush, like *Opuntia tuna*.

Family ASCLEPIADACEÆ: Milkweed Family.

*Gomphocarpus fruticosus* (L.) R.Br. in Mem. Wern. Soc. 1, 38 (1809). SHRUBBY MILKWEED. Native of the Mediterranean region; naturalised in Australia, where it was introduced with the early colonists and long since established near Port Jackson and other parts of New South Wales, *R. Brown* and others. Has over-run many places in the southern colonies of Australia; but when by chance it has been introduced into Queensland, it has not taken kindly to the climate, preferring a dry, rather than a damp summer heat, *F. Manson Bailey*. In Natal it occurs between 3,000 and 4,000 ft. alt., *J. M. Wood*.

In the Transvaal it is a common and untidy weed of roadsides, vacant erven and town commonage: Pretoria, alt. 4,400 ft., a common weed, Feb., 1904, *Davy*; Irene, alt. 4,800 ft., a common weed, Nov. 1, 1903, *Davy* 741; Fourteen Streams, a common weed, Feb. 14, 1904, *Davy* 1565.

Family BORAGINACEÆ: Borage Family.

*Cynoglossum micranthum*, Desf., Tabl. ed. 1, 220. HOUNDS-TONGUE. Native of the Himalaya and Burma, up to 8,000 ft. alt., *Hooker*. It is found in Natal from 1,000 to 4,000 ft. alt., *J. M. Wood*. In the Transvaal this is a troublesome weed on vacant erven and roadsides in towns; the seed-like fruits stick closely to the clothing and are easily transported from place to place in this manner. Waterval Boven, alt. 4,800 ft., a troublesome weed, Feb. 4, 1904, *Davy* 1431; Belfast, alt. 6,400 ft., a common and troublesome weed on town streets and vacant erven, Feb. 8, 1904, *Davy* 1472; Standerton, alt. 5,000 ft., not uncommon, Jan. 5, 1904, *Davy* 902.

*Lithospermum arvense*, Linn. Sp. Pl. 132 (1753). CORN GROMWELL. Native of Europe, N. Africa, N. and W. Asia, and N.W. India. Introduced in the United States, Natal, etc. Adventive in oat stubble in the Transvaal:—Pretoria, Skinner's

Court, a solitary specimen, Aug. 19, 1903, *Davy* 586; Potchefstroom, alt. 4,500 ft., a few specimens, Nov. 1904, *Davy*. Hooker states that this plant yields a red dye.

Family CACTACEÆ: Cactus Family.

*Opuntia ficus-indica*, Mill., Gard. Dict. ed 8. n. 2. PRICKLY PEAR. Native of South America and the West Indies; extensively naturalised in parts of S. Europe, N. Africa, Australia, and Cape Colony, where it has become a veritable pest, occupying hundreds of acres of valuable land, and where it is now so thoroughly established that it would be impracticable, if not impossible, to exterminate it. From Cape Colony it was carried by the Boers to the Transvaal, where it was planted for hedges around gardens and orchards. In the northern districts it has been carried by the natives to the bush around their kraals, for the sake of the fruit, which is eaten by them. It is now spreading slowly into the bush, particularly below 4,500 ft. alt. It is common in the Marico, Waterberg and Zoutpansberg Districts. Near Zeerust, in the bush, June, 1903, *Davy*; near Nylstroom, November, 1903, *Davy*. Reported to be common and spreading in Sekukuni's country; also reported from near Heidelberg. It is almost certain that *O. tuna*, Mill. and *O. monacantha*, Haw. are included in the reported distribution of the "Prickly Pear." The three species have for long been mistaken the one for the other. Probably all three occur in South Africa. *O. monacantha* appears to be common in Natal.

Family CAPPARIDACEÆ: Caper Family.

*Gynandropsis pentaphylla* (L.) DC. Prodr. 1 : 238. MOSAMBE, Brède caya. Native of the West Indies, now naturalised throughout the tropics. Early introduced into South Africa, as Burchell collected it at the Asbestos Mts. Transvaal:—Magaliesberg, Zeyher; Warm Baths, alt. 3,500 ft., not uncommon, Nov., 1903, *Davy* 1760; Fourteen Streams, a common weed, Feb. 14, 1904, *Davy* 1567. It is said that a seed-pod, placed in the ear, will quickly extract any accumulations of wax.

Family CARYOPHYLLACEÆ: Pink Family.

*Silene gallica*, Linn., Sp. Pl. 417 (1753). GUN-POWDER WEED (the black seeds resemble gunpowder, *Flora Capensis*). Considered to be indigenous to Europe, N. Africa, Siberia and N. and W. Asia to India, *Hook. f.* Naturalised elsewhere (California, Cape Colony, Natal below 1,000 ft., the Transvaal, etc.) A troublesome weed in cultivated ground and (in California) on cattle ranges. In the Transvaal it is adventive, but not yet common, though showing signs of spreading on the High Veldt:—Belfast, not uncommon on ballast at the R.R. Station (alt. 6,446 ft.) at the old Repatriation Camp site, and on town erven, Feb. 7, 1904, *Davy* 1389; Potchefstroom (alt. 4,500 ft.), a single plant among oak stubble, Government Experiment Farm, Oct. 10, 1903, *Davy* 1761.

*Spergula arvensis*, Linn. Sp. Pl. 440 (1753). SPURREY, Corn spurrey. Native of Europe (Arctic), N. Africa and W. Asia to N.W. India; an alien in N. America and S. Africa. A weed in cultivated ground in Cape Colony, *Flora Capensis*, 1860; a weed in Natal between 1,000 and 2,000 ft. alt., *J. M. Wood*. Adventive in the Transvaal:—Potchefstroom, alt., 4,500 ft., adventive with seed oats on the Government Experiment Farm, Dec. 27, 1903, *Davy* 840; Belfast, alt. 6,446 ft., several plants on ballast at the railroad station, where they get moisture from the water-tank overflow, Feb. 7, 1904, *Davy* 1392.

*Stellaria media*, Cyrill., Char. Comm. 36 (1784). CHICK-WEED. Hooker considers this plant to be indigenous to "all Arctic and North Temperate regions; naturalised elsewhere." Cape Colony. "a weed in cultivated ground everywhere; introduced from Europe," *Flora Capensis*, 1860. Natal, below 1,000 ft. alt., *J. M. Wood*. Sparingly met with in the Transvaal, in damp, shady places in or near town gardens; apparently not well adapted to the climatic conditions of the High Veld:—Pretoria, alt., 4,400 ft., between the bricks of a shady water furrow on Schoeman Street, March 16, 1904, *Davy* 1751; Johannesburg, alt. 5,700 ft., in a shady garden near Rissik Street, April, 1904, *Davy*.

*Vaccaria vulgaris*, Host. Fl. Austr. 1 : 518. COW-HERB. Native of Southern Europe, Asia Minor and Siberia; naturalised in North America and S. Africa. Adventive in the Transvaal, and likely to become a troublesome grain-field weed, as it is in California and Nevada:—Pretoria, alt. 4,400 ft., a single plant in oat-stubble at Skinner's Court, Feb. 1, 1904, *Davy* 1191; Standerton, several plants on the farm Beginsel, in the border of an old garden, March 29, 1904, *Davy* 1796; Potchefstroom, alt. 4,500 ft., a few plants adventive in stubble, Nov., 1903, *Davy* 1816. The seeds are poisonous.

#### Family CHENOPODIACEÆ: Goosefoot Family.

*Chenopodium album*, Linn. Sp. Pl. 219 (1753). FAT-HEN, White goosefoot, Meld-weed, Epinard sauvage; occasionally called Pigweed, but this name is more generally applied to the Amaranths. Native of Europe (Arctic) and temperate Asia; an alien in N. America. Ascends to 1,000 ft. in Yorkshire, *Hook f.* Not reported by Mr. J. M. Wood from Natal. Widely distributed in the Transvaal as a casual garden weed, but nowhere nearly so abundant as the Amaranths:—Lydenburg, a casual garden weed, June 15, 1903, *Davy* 399; Potchefstroom, alt. 4,500 ft., a common garden weed, Dec. 27, 1903, *Davy* 1772; a farm weed, Jan. 24, 1904, *Davy* 1224; Pretoria, alt. 4,400 ft., common on streets, waste places and vacant erven, Jan. 28, 1904, *Davy* 1076; Haaman's Kraal Railroad Station, alt. 3,389 ft., a ballast weed Jan. 30, 1904, *Davy* 1106; Belfast, a garden weed at farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy* 1260; Christiana, alt. cir. 4,100 ft., a common garden weed, Feb.

16, 1904, *Davy 1619*; Standerton, a casual garden weed at farm Beginsel, March 29, 1904, *Davy 1801*.

*Chenopodium ambrosioides*, Linn. Sp. Pl. 219 (1753). MEXICAN TEA, Ibigicana, Herbe pipi, Thè du Mexique. Native of tropical America, naturalised in the United States. Natal, below 1,000 ft. alt., an alien, *J. M. Wood*. Adventive in the Transvaal and likely to spread:—Potchefstroom, alt. 4,500 ft., a common roadside weed, Dec. 27, 1903, *Davy 1036*; Warm Baths, a common farm weed, Jan. 30, 1904, *Davy 1206*; Water-val Boven, alt. 4,826 ft., an occasional ballast weed, Feb. 4, 1904, *Davy 1457*; Pretoria, alt. 4,400 ft., a common weed on vacant erven and by roadsides March 20, 1904, *Davy*.

*Chenopodium botrys*, Linn. Sp. Pl. 219 (1753). JERUSALEM OAK. Native of South Europe. Natal, between 1,000 and 3,000 ft. alt., an alien, *J. M. Wood*. Occasional in the Transvaal as an adventive weed:—Standerton, alt. 5,000 ft., an occasional weed on vacant erven and by roadsides, March 28, 1904, *Davy 1780, 1786*; Pretoria, alt. 4,400 ft., occasional garden weed, April, 1904, *Davy*; Barberton, in bush, 1904, *Thorncroft 561*, in Natal Government Herbarium.

*Chenopodium murale*, Linn. Sp. Pl. 219 (1753). NETTLE-LEAVED GOOSEFOOT. Native of Europe, N. Africa, W. Asia, and N.W. India; introduced in N. America and S. Africa. Natal, between sea-level and 2,000 ft. alt., *J. M. Wood*. An occasional garden and roadside weed in the Transvaal:—Lydenburg, a garden weed, June 15, 1903, *Davy 398*; Pretoria, alt. 4,400 ft., an occasional roadside weed in shady places, Jan. 4, 1904, *Davy 834*.

*Chenopodium polyspermum*, Linn., Sp. Pl. 220 (1753). Native of Europe and Northern Asia. Christiana, Feb. 15, 1904, *Davy 1616*. The single specimen secured was gathered under most adverse conditions, and is not complete, so that I cannot be certain as to the species; it had quite a different aspect from the specimens of *C. album* collected at the same time and which were growing near it.

#### Family COMPOSITÆ: Sunflower Family.

*Anthemis cotula*, Linn. Sp. Pl. 894 (1753). STINKING CHAMOMILE, Stinking may-weed. Native of Europe, N. and W. Asia, W. India; an alien in N. America and S. Africa. Adventive in the Transvaal; likely to spread and to become a troublesome farm and garden weed, as it has done in California:—Potchefstroom, alt. 4,500 ft., a few vigorous plants, Dec. 27, 1903, *Davy 843*; Belfast, alt. 6,400 ft., a few plants on roads and vacant erven, Feb. 6, 1904, *Davy 1347*; Standerton, occasional in an old garden on farm Beginsel, March 29, 1904, *Davy 1799*. The plant is acrid and emetic and the foliage is said to blister the hands.

*Bidens pilosa*, Linn. Sp. P. 832 (1753). BLACK-JACK, Beggar-ticks, Wewenaar, Widowers, Sweethearts, Um-sheeje,

La Ville-bague; also miscalled Klits-gras, a name more generally applied to *Setaria verticillata*. Native of the W. Indies and S. America; now become a common tropical and subtropical weed. Introduced into S. Africa at an early date, as it is recorded to have occurred as a weed in the Eastern Districts of Cape Colony and at "Port Natal" in the *Flora Capensis* (1865). It is now found in Natal between sea-level and 5,500 ft. alt., *J. M. Wood*. One of the most common and most troublesome weeds in the Transvaal, but like other "common" plants, seldom collected:—Pretoria, alt. 4,400 ft., June, 1903, *Davy*.

*Bidens pilosa leucantha* (Willd.) Harv., Fl. Cap. **3** : 133 (1864-65). BLACK-JACK, Beggar-ticks, Wewenaar. Common along the coast of Natal, between 1,000 and 3,000 ft. alt., *J. M. Wood*, and in the Low-country of the Transvaal at Barberton, etc., but not commonly met with on the High Veld. It appears to be spreading eastward and upward along the railway:—Avoca Station, June 8, 1903, *Davy* 242; Barberton, June, 1903, said to be a bad weed all through the agricultural region, and to be the first weed to appear on newly-broken ground; Waterval Boven, alt. 4,826 ft., common, Feb. 4, 1904, *Davy* 1460; Belfast, alt. 6,400 ft., common, Feb. 5, 1904, also common at farm Rietvlei, alt. 6,000 ft., Feb. 8, 1904, *Davy* 1468; Pretoria, alt. 4,400 ft., only two specimens, on the shaded bank of a damp furrow, Troye Street, Sunnyside, March 13, 1904, *Davy* 1757.

*Chrysanthemum segetum*, Linn., Sp. Pl. 889 (1753). CORN MARIGOLD, Gowan. Native of Europe, N. Africa and W. Asia. Harvey states (1865) that it had already penetrated "the bush" 50 miles beyond the Kei, but it does not appear to have established itself, for in 1903 Bolus and Woolley-Dod reported it as "rare" on the Cape Peninsula. In the Transvaal I have found it in only one locality, viz., Belfast, alt. 6,446 ft., where it was common at the railway station and at the old Repatriation Camp site, Feb. 5, 1904, *Davy* 1388.

*Conyza podocephala*, DC. Prodr. **5** : 387. A native of the Cape Colony, which appears to be an alien in the Transvaal, at least on the High Veld, where it is not uncommon by roadsides and water-courses:—Pretoria, alt. 4,400 ft., common in moist and swampy places along the Aapjies River, Dec. 13, 1903, *Davy* 800; Christiana, alt. cir. 4,100 ft., an occasional weed by roadsides and in moist places, Feb. 15, 1904, *Davy* 1610.

*Cosmos bipinnatus*, Cav., Icon. **1** : 9. tt. 14, 79 (1791). COSMOS. Native of Mexico and South America; extensively cultivated for ornament, in gardens in Europe, the United States, S. Africa, etc. An occasional garden escape in the Transvaal:—Pretoria, alt. 4,400 ft., a garden escape at Skinner's Court, thoroughly naturalised, Feb. 1, 1904, *Davy* 1189; abundantly naturalised along the railway near Roodepoort and Florida, alt. cir. 5,700 ft., and Zuurfontein, alt. 5,456 ft., March 26, 1904.

*Cotula australis*, Hook f., Fl. Nov. Zel. 128. Native of Aus-



tralia, New Zealand, Tasmania, and Tristan d'Acunha; naturalised in California. This species is very close to the common Asiatic and African *Cotula anthemoides*, L. of Egypt, Nubia, Bechuanaland, Natal, and Cape Colony, and cannot always be readily distinguished from it. In the Transvaal it occurs very sparingly in shady, damp places:—Lydenburg, a few plants along the water-furrow of the main street, June 15, 1903, *Davy* 402; Pretoria, alt. 4,400 ft., an occasional weed along water-furrows, Oct.-Nov., 1903, *Davy* 1773.

*Cryptostemma calendulaceum*, R.B. in Ait. Hort. Kew, ed. 2, 5 : 141. CAPE-WEED, Gouds-bloem. Native of Cape Colony, where it is "very common in roadsides and waste places throughout the Colony." (*Flora Capensis*); naturalised in parts of Australia, where it has become a troublesome weed. In Natal it occurs between 1,000 and 2,000 ft. alt., *J. M. Wood*. I have not seen any Transvaal specimens, but it was reported by an Australian farmer as occurring on a dam on the Springbok Flats in Nov., 1903.

*Erigeron canadensis*, Linn., Sp. Pl. 863 (1753). HORSE-WEED. Native of North America, but now introduced into most temperate and warm countries. Reported from the Eastern Districts of Cape Colony and from Natal in 1865, *Flora Capensis*. A common garden and farm weed in the Transvaal, where it seems thoroughly at home and where it is likely to spread rapidly and to cause much trouble in Lucerne fields. It seeds profusely and during a long season. Pretoria, a common orchard weed at Hartebeeste-nek Nov. 14, 1903, *Davy* 783; a common weed in cultivated ground on vacant erven, and by roadsides in the town, Dec. 13, 1903, *Davy* 797; Waterval Boven, alt. 4,826 ft., a common weed, Feb. 4, 1904, *Davy* 1429; Belfast, a garden weed at farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy* 1254; Warm Baths, a troublesome weed in a Lucerne patch, March, 1904. In Natal it occurs below 3,000 ft. alt., *J. M. Wood*.

*Gnaphalium luteo-album*, Linn. Sp. Pl. 851 (1753). Probably native of Southern Europe, now almost cosmopolitan, and found in Europe, Asia, N. and S. Africa, Australia, St. Helena, Brazil, etc. It was frequently met with in the Eastern Districts of Cape Colony and in Natal in 1865. In Natal it occurs between sea-level and 2,000 ft. alt., *J. M. Wood*. Not uncommon in the Transvaal, as a roadside weed, in damp places:—Pretoria, alt. 4,400 ft., common, Dec., 1903, *Davy* 801; Belfast, 6,400 ft. alt., a common weed in town, Feb. 5, 1904.

*Hypochaeris radicata*, Linn., Sp. Pl. 810 (1753). GOSMORE, Cat's-ear. Native of Europe and N. Africa; naturalised and become a troublesome pasture weed in parts of Australia and California. It does not appear to have been previously recorded from South Africa, and I have found but a single specimen:—Belfast, alt. 6,446 ft., a solitary plant on the old Repatriation Camp site, Feb. 7, 1904, *Davy* 1395. This is such an injurious pasture-weed that it is to be hoped it will not become naturalised with us.

*Nidorella auriculata*, DC., Prodr. **5**: 322. Var.  $\gamma$  (?) Native of South Africa. What appears to be a variety of this species is occasionally met with as a roadside weed in the Transvaal, having all the aspect of an introduced plant.

*Osteospermum muricatum asperum*, Harv., Fl. Cap. **3**: 441 (1864-5). Native of Somaliland; also found in Natal (from 3,000 to 4,000 ft. alt.), Zululand and others parts of S. Africa. In the Transvaal it occurs as a roadside weed and is apparently not indigenous:—Pretoria, alt. 4,400 ft., a roadside weed, May 11, 1903, *Davy* 16; Hartebeeste-nek, a weed, Nov. 14, 1903, *Davy* 755.

*Sonchus oleraceus*, Linn., Sp. Pl. 794 (1753). Sow-THISTLE, Milk-thistle. Native of Europe, N. and W. Asia, India, N. Africa, S. Australia, New Zealand, *Hook. f.*; introduced in America and S. Africa. In Natal it is found between sea-level and 4,000 ft. alt., *J. M. Wood*. In the Transvaal it occurs as an occasional weed in gardens:—Lydenburg, along water-furrows in the town, June 16, 1903, *Davy* 412; Potchefstroom, Nov., 1903.

*Tagetes erecta*, Linn., Sp. Pl. 887 (1753). AFRICAN MARI-GOLD. Native of Mexico; a favourite garden flower. An occasional garden escape in the Transvaal, and, like other Mexicans (e.g., *Cosmos*, *Zinnia* and *Ipomoea purpurea*) showing signs of becoming naturalised:—Irene, alt. 4,800 ft., naturalised in an old brick-yard, May 6, 1903, *Davy* 23; Waterval Boven, alt. 4,826 ft., an escape in the borders of the town, Feb. 4, 1904, *Davy* 1433; Zuurfontein Railroad Station, alt. 5,400 ft., an escape, April, 1904.

*Taraxacum officinale*, Weber, in Wigg. Prim. Fl. Holsat. 56. DANDELION. Indigenous to the Arctic and parts of the N. and S. temperate regions; naturalised in California. In the Transvaal it occurs sparingly as a naturalised weed in the borders of gardens and beside water-furrows:—Potchefstroom, alt. 4,500 ft., common in the border of gardens near water-furrows, Dec. 27, 1903, *Davy* 1037. The dried roots are a well-known medicine and are also ground as a coffee substitute; the leaves are eaten as salad.

*Tragopogon porrifolius*, Linn., Sp. Pl. 789 (1753). SALSIFY. Native of the Mediterranean region; cultivated in gardens for the sake of its edible roots, and frequently met with as an escape in California, etc. In the Transvaal I have found only a single spontaneous specimen, but it is likely to become established here sooner or later:—Potchefstroom, a garden escape at Haaskraal, Jan. 24, 1904, *Davy* 1218.

*Xanthium spinosum*, Linn., Sp. Pl. 987 (1753). BURR-WEED, Spiny clot-bur, Boete-bosjie, Pinoti-bosjie. Native of the Old World tropics, *Gray*; now cosmopolitan. A most pernicious weed, against which laws have been enacted in Cape Colony, Natal, the Orange River Colony and the Transvaal, on the ground that the burrs are "particularly injurious to the wool-cleaning machines, and therefore [it is] to be destroyed under fine." The spread of this weed is a serious menace to the stock-



raising industries of South Africa, particularly those of wool and mohair production. The "burrs" are covered with sharply-hooked prickles, by which they become tangled in the wool of sheep, the hair of goats, and the tails and manes of horses, mules and donkeys. They not only cause irritation and annoyance to the animals, which seriously checks their growth, but greatly diminish the commercial value of the wool and mohair. In the Transvaal this weed is most abundant on the southwestern borders, where it appears to have been brought in with stock from the Orange River Colony, Griqualand West and Bechuanaland; it is reported that there is some on practically every farm in the Bloemhof and Wolmaransstad Districts, but only in small patches and around the homesteads, along roadsides, in vleis and along other water-courses; it is most abundant on town roads and water-furrows. Potchefstroom is badly infested with the weed. The eastern districts are nearly free from it, but a few plants are to be found in almost every town, and from these it is likely to spread to every farm, unless they are systematically eradicated.

I have noted it in abundance at Fourteen Streams, Christiana, Bloemhof, Schweizer-Reneke, Wolmaransstad, Klerksdorp, Potchefstroom and Johannesburg:—At Pretoria, alt. 4,400 ft. (common), Haaman's Kraal Railway Station, alt. 3,389 ft., Jan. 30, 1904, *Dary 1105*; Warm Baths (common), Belfast, alt. 6,446 ft. (only about a dozen plants); Waterval Boven, alt. 4,800 ft. (a few plants); Standerton, alt. 5,000 ft. (a few plants).

*Xanthium strumarium*, Linn., Sp. Pl. 987 (1753). (?) COCKLE-BURR. Native of the Old World tropics, *Gray*; now almost cosmopolitan. It has become a bad pest in Australia and Natal (from sea-level to 2,000 ft. alt., *J. M. Wood*); it is a casual weed in England. In the Transvaal I have seen only one clump of specimens (near Pretoria) and as they were then immature, I am not yet certain as to the identity of the species.

*Zinnia pauciflora*, Linn., Sp. Pl. ed. 2, 1269. ZINNIA. Native of Mexico and S. America, largely cultivated as an ornamental garden plant. In 1865 it was reported as "common on the eastern frontier of Cape Colony and Natal, as an escape from cultivation, *Flora Capensis*. In Natal it occurs from 1,000 to 3,000 ft. alt., *J. M. Wood*. It is now one of the commonest roadside weeds in many parts of the Transvaal:—Pretoria, a common roadside weed, May, 1903; Magaliesberg, a common weed in cultivated ground, farm Hartebeeste-nek, Nov. 14, 1903, *Dary 784*.

Family CONVULVACEÆ: Convolvulus Family.

*Ipomœa purpurea*, Roth, Bot. Abh. 27. MORNING GLORY, *Convolvulus major*. Native of tropical America, commonly cultivated as an ornamental garden plant, and frequent as an escape in the United States, Mauritius, South Africa, etc. In Natal it occurs between sea-level and 1,000 ft. alt., *J. M. Wood*. Waterval Boven, alt. 4,826 ft., a garden escape, Feb. 4, 1904, *Dary*

1450; Belfast, farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy 1251*; Pretoria, railway cutting at Daspoort, Feb. 1904; Potchefstroom, alt. 4,500 ft., an escape on vacant erven, March 25, 1904.

Family CRUCIFERÆ: Cabbage Family.

*Barbarea præcox*, R.Br. in Ait. Hort. Kew—ed. 2, **4** : 109. (?) Native of Europe; in 1865 reported as a weed in cultivated ground in Cape Colony, *Flora Capensis*. What appears to be this species is an occasional weed in moist, shady places along water-furrows and the borders of gardens in Pretoria.

*Brassica campestris*, Linn., Sp. Pl. 666 (1753). WILD RAPE. Probably a native of S.E. Europe and S.W. Asia; cultivated all over the civilised world, and found as a weed in cultivated ground. Standerton, alt. 5,000 ft., a casual weed in the hotel yard, Jan. 5, 1904, *Davy 894*; farm Beginsel, a casual weed in an old garden, March 29, 1904, *Davy 1798*.

*Brassica nigra*, Koch, in Roehl. Deutschl. Fl. ed. 3, **4** : 713. BLACK MUSTARD. Native of Europe, N. Africa and W. Asia eastward to the Himalaya; cultivated throughout the world, and naturalised in the United States; common as an escape in England. Standerton, an immigrant in a garden on the farm Beginsel, March 30, 1904 *Davy 1795*.

*Capsella bursa-pastoris*, Medic. Pflanzeng. 85 (1792). SHEPHERD'S PURSE. Native of Temperate and Arctic Europe, N. Africa and Asia, eastward to the Himalaya; introduced into all temperate climates; ascends to 1,200 ft. alt. in the British Islands, *Hook. f.* In 1860 recorded as occurring in cultivated ground throughout Cape Colony, *Flora Capensis*. I have found only a solitary specimen in the Transvaal:—Belfast, on ballast at the railway station, alt. 6,446 ft., Feb. 7, 1904, *Davy 1391*.

*Coronopus didymus* (L.) Smith, Fl. Brit. **2** : 691. WART-CRESS. Native of temperate South America; a colonist elsewhere, *Hook, f.* Naturalised in England, California, S. Africa, etc. In Natal it occurs below 1,000 ft. alt., *J. M. Wood*. In 1860 it was recorded as occurring on waysides and on rubbish about Capetown, *Flora Capensis*. In the Transvaal I have seen it only in Pretoria, where a few plants occur at the foot of a stone foundation at the corner of St. Andries and Pretorius Streets, March 17, 1904, *Davy 1749*; it also occurs in a garden in Sunnyside.

*Lepidium capense*, Thunb., Prodr. Pl. Cap. 107. CAPE PEPPER-CRESS. Supposed to be a native of Cape Colony; in Natal it occurs below 1,000 ft. alt., *J. M. Wood*. In the Transvaal it appears to be an alien, and is one of the most abundant of our roadside weeds, but seldom collected:—Pretoria, alt. 4,400 ft., a common roadside weed, Nov. 29, 1903, *Davy 822*; Belfast, alt. 6,400 ft., a common weed, Feb. 8, 1904, *Davy 1466*.

*Nasturtium officinale*, R.Br. in Ait. Hort. Kew. ed. 2, **4** : 111. WATER-CRESS. Native of Europe. In 1860 reported as occurring "in streams and ditches near Capetown, and at Krakukamma, Uitenhage, *Flora Capensis*. In the Transvaal I have

only found it in Pretoria, in the Aapies River and its tributaries, where it is said to have been intentionally introduced some years ago. It is reported as common in certain fontains near Morgenzon, north-east of Standerton, though not at Morgenzon itself.

*Raphanus raphanistrum*, Linn., Sp. Pl. 669 (1753). JOINTED CHARLOCK, White charlock, Runch; also called Wild radish, but this name is more properly applied to *R. satius*, which in some countries has become naturalised as a common and troublesome weed. Native of Europe (Arctic), N. Africa, N. and W. Asia eastward to India, *Hook. f.*; a colonist in England, *Wats.*; introduced in America, *Hook. f.* Adventive in the Transvaal:—Potchefstroom, alt. 4,500 ft., a few specimens in stubble, Nov. 1903, *Davy 1815*; Belfast, alt. 6,446 ft., common at the railway station and the old Repatriation Camp site, Feb. 7, 1904, *Davy 1385*.

*Sisymbrium capense*, Thunb., Prodr. Pl. Cap. 109; *Flora Capensis* 497. CAPE MUSTARD. Native of Cape Colony; found also in Natal, below 1,000 ft. alt., *J. M. Wood*. In the Transvaal it is evidently an alien:—Standerton, alt. 5,000 ft., a common weed of roadsides and vacant erven, Jan. 5, 1904, *Davy 896*.

#### Family CYPERACEÆ: Sedge Family.

*Cyperus esculentus*, Linn., Sp. Pl. 45 (1753). FINCHES, Uintjes, Um-tata. Found in all tropical and warm temperate regions except Malaya, Australia and Oceania, *C. B. Clarke*; a troublesome weed in Natal. Evidently an alien in the Transvaal, where it is a troublesome orchard and garden weed. It is difficult to eradicate, as the plants produce underground tubers which break off easily when the plants are pulled or dug out, and each of which will form a new plant:—Pretoria, 4,400 ft. alt., *Rehmann 4776*; Houtbosch, *Rehmann 5654*; Pretoria, a troublesome weed around fruit trees in orchards at Hartebeeste-nek, Nov. 14, 1903 *Davy 765*; Potchefstroom, alt. 4,500 ft., a common garden weed, Dec. 27, 1903; *Davy 851, 1769*; Ermelo, troublesome in orchards, Jan. 8, 1904, *Davy 973*; Warm Baths, a common weed in cultivated land, Jan. 31, 1904, *Davy 1161*; Belfast, a plentiful and troublesome garden weed, farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy 1255*.

*Mariscus sieberianus*, Nees in Linnæa **9** : 286. (*Cyperus steudelianus*, Bœckl., in Linnæa **36** : 382 (1869-70). Native of Tropical Africa. Barberton, a weed in the Turton orchard, Moody Concession, eight miles west of town, June 9, 1903, *Davy 251*; reported to be a troublesome weed, but my informant may have been mistaken as to the identity of the species.

#### Family EUPHORBIACEÆ: Castor-bean Family.

*Euphorbia sanguinea*, Hochst. and Steud. ex Boiss. in DC. Prodr. **15** : Pt. 2, 35. Native of Tropical Africa. A common garden weed in Pretoria; possibly indigenous.

*Ricinus communis*, Linn., Sp. Pl. 1007 (1753). CASTOR-BEAN, Castor-oil bush, Palma Christi. Native of India and possi-

bly also of Tropical Africa; now extensively cultivated and naturalised in S. Europe, N. and S. Africa, the southern and south-western United States, etc. Natal, from sea-level to 3,000 ft. alt., *J. M. Wood*; common in the bush near Durban. Not uncommon in the Transvaal, particularly below 4,500 ft. alt.; Pretoria, Barberton, etc.

*Ricinus communis lividus*, Jacq. (*R. sanguineus*, Hort. ex Groenland in Rev. Hort. Sér. 4, **7** : 601 (1858); see also Rev. Hort. Sér. 4, **7** : 182, 183). SCARLET CASTOR-BEAN. Pretoria, along the railway track near the Fountains, Feb. 25, 1904.

Family GRAMINEÆ: Grass Family.

*Andropogon halepensis effusus*, Stapf. in Hook. Fl. Brit. Ind. : 183 (*Sorghum halepense*, Pers., var.) JOHNSON-GRASS, Ever-green millet. Native of the Mediterranean Region (S. Europe, N. Africa, Asia); it occurs throughout the tropics, but particularly in Africa. In S. Africa it is found in Natal, Pondoland, Tembuland, Little Namaqualand, Komgha and Knysna, *Stapf*. The form from which the species was originally described is apparently only a weaker state with smaller spikelets, *Stapf*. In Natal, Mr. J. Medley Wood reports that it occurs between 1,000 and 2,000 ft. alt., but that it is not common. In the Transvaal it appears to be extremely local, and is often, if not always, a colonist:—Zeerust, along the Groot Marico River, May 22, 1903, *Davy* 122; Barberton, becoming a troublesome weed in Turton's orchard, Moody Concession, June 9, 1903, *Davy* 248; Haaman's Kraal Railway Station, alt. 3,389 ft., a solitary specimen, Jan. 30, 1904, *Davy* 1088; Springbok Flats, a few specimens on farm Tweeklaagte, Jan. 30, 1904, *Davy* 1128; Warm Baths, not uncommon as a farm weed, Jan. 31, 1904. One of the worst weeds of cultivation.

*Andropogon sorghum*, Brot., Fl. Lusit. **1** : 88. The Kaffir-corns and a *Sorghum* are cultivated by the natives of the Transvaal, for food, and for the preparation of a Kaffir beer. I have not found any of them growing spontaneously in the Transvaal, even as escapes, but they are included here because there are some Transvaal records for them in the books, and in order to call attention to them with a view to eliciting information.

*Andropogon sorghum Nesii*, Körn. in Baumann, Usambara, 319. WHITE KAFFIR-CORN. Found in the Koosa country and from Wilge-bosch Spruit, in the Orange River Colony (?); Kaatjes Kraal, Knysna Div., *Burchell* 5278; Takun, Bechuana-land, *Burchell* 2214 teste *Stapf*. Said to be grown also in various parts of tropical Africa, *Stapf*. A white Kaffir-corn, which is probably this variety, is cultivated by the natives of the Transvaal on the High Veld and probably elsewhere.

*Andropogon sorghum Schenkii*, Körn. in Baumann, Usambara, 319. RED KAFFIR-CORN. *Type locality*: "Bosch Veld, north of the Magalies Mountains, in the Transvaal, *Schenk*."

Said to be grown also in various parts of Tropical Africa." *Stapf*. A red Kaffir-corn which is probably this variety, is cultivated by natives on the High Veld; *Stapf* does not state whether Schenk's plant was growing spontaneously or in cultivation.

*Andropogon sorghum saccharatus* (L.) Körn. in Körn. and Wern. Handb. d. Getreidebaues 310. SORGHUM, Imphee, Sweet sorghum, Sugar sorghum. *Stapf* states that this is said to be the commonest form grown in Tropical Africa, and that it is also cultivated in Tropical Arabia, India, Southern Europe, and the United States. It is grown by the natives of the Transvaal to a limited extent, for the sake of the sweet canes, which they are fond of chewing. It does not appear to be grown to nearly as great an extent as the Kaffir corns.

*Arundo donax*, Linn., Sp. Pl. 81 (1753). GIANT REED. Native of the eastern Mediterranean region and the Orient; largely cultivated for ornament and naturalised as a garden escape in many warm-temperate countries. Frequently cultivated, in the Transvaal, for ornament, and occasionally found as an escape:—Crocodile River, north of the Magaliesberg, June, 1903.

*Avena sativa*, Linn., Sp. Pl. 79 (1753). COMMON OATS. Probably of Mediterranean Region origin, *Stapf*: widely cultivated for corn and forage in the temperate regions of both hemispheres. In the Transvaal it occurs sparingly as an escape from cultivation or from scattered horse-feed:—Belfast, site of old Repatriation Camp, alt. 6,446 ft., Feb. 7, 1904, *Davy* 1383.

*Bromus Willdenowii*, Kunth, Rev. Gram. 1 : 134 (*B. unioloides*, Auct. not of Willd.) RESCUE-GRASS, Prairie-grass, Schrader's brome-grass. Native of S. America and Mexico, perhaps also of the south-western United States from the Indian Territory and Texas to Arizona and Southern California; introduced into Alabama, N. California, Southern Europe, India, Southern Australia, Tristan D'Acunha, S. Africa, etc.; often grown for forage. In the Transvaal it appears to have been introduced with garden or farm seeds, perhaps from Australia, or perhaps with forage. It is sparingly naturalised in shady places, but does not appear to take kindly to the climate, it is usually depauperate and has a "starved" aspect:—Lydenburg, moist, shady places, June 16, 1903, *Davy* 413; Potchefstroom, occasional at Haaskraal, Oct. 10, 1903, *Davy* 1764, shady orchards in town, Dec. 27, 1903, *Davy* 1767; Warm Baths, alt. 3,500 ft., in the shade of a Banana plantation, Nov. 1903, *Davy* 1759; Belfast, an orchard weed at farm Rietvlei, alt. 6,000 ft., common under trees, but depauperate except where it gets a little irrigation, Feb. 5, 1904, *Davy* 1265. It is said that horses refuse to eat it when it has grown in the shade.

*Chloris virgata*, Swartz, Fl. Ind. Occ. 1 : 203. RHODES' GRASS, Chloris, Sweet-grass, Blue-grass. Widely spread through

the tropics of both hemispheres, *Stapf*. Common throughout S. Africa; apparently an alien in the Transvaal, at least on the High Veld, where it is most abundant along roads, in old maize or oat fields and in vleis:—Near Lydenburg, *Atherstone*; Zee-rust, a weed in cultivated land at Willow Park Farm, May, 1903, *Davy 561*; Pretoria, alt. 4,400 ft., a common weed in cultivated land, October, 1903, *Davy 1774*; Standerton, alt. 5,000 ft., a common weed, Jan. 5, 1904, *Davy 907*; Haaman's Kraal Railroad Station, alt. 3,389 ft., Jan. 30, 1904, *Davy 1090*. A valuable annual hay-grass, much liked by stock when properly cured.

*Cynodon dactylon* (L.) Pers. Syn. Pl. 1: 85. BERMUDA-GRASS, Dog's-tooth grass, Doub, Doob, Dub, Regte kweek-gras, Tweek-grass, Chien-dent. Indigenous throughout India, where it ascends to 5,000 ft. alt.; now almost cosmopolitan, occurring all around the world in the two warmer zones. In Natal it occurs below 1,000 ft. alt. *J. M. Wood*. In the Transvaal it appears to be an alien, it is common around homesteads, outspan places, roadsides and vacant erven in towns and villages:—Houtbosch, *Rehmann 5713*; near Lydenburg, *Wilms 1701*; Pretoria, a troublesome weed in orchards, Hartebeeste-nek, Nov. 14, 1903; Fourteen Streams, common, Feb. 14, 1904, *Davy 1585*; Schweizer Reneke, common around farmstead, Vierfontein, Feb. 17, 1904, *Davy 1634*. The principal pasture plant in many warm, dry climates, but a most injurious weed in orchards, gardens and farm lands, where it is almost impossible to eradicate it if once well established.

*Dactyloctenium ægyptium* (L.) Willd. Enum. Pl. Hort. Berol. 1029 (1809). CROWFOOT-GRASS, Duck-grass, Chiendent patte de poules; original home uncertain; now widely spread throughout the tropical and sub-tropical regions of both hemispheres, *Stapf*. Commonly naturalised in the Southern United States and sparingly in California. It is occasional in the Coast region of Cape Colony, near the mouth of the Kei River, etc.; also in the Eastern region; in Pondoland, on the shore between the Umtsikaba and Umtentu Rivers; on the Durban Flats, and elsewhere near Durban and at Delagoa Bay. In the Transvaal this grass appears to be an alien, at least on the High Veld and in the Bush Veld, but it is possibly indigenous to the Low-country north and east:—Klippan, in the Bosch-veld, *Rehmann 5357*; Warm Baths, alt. 3,524 ft., a common weed along the road from the railroad station to the baths, Dec. 1903, *Davy 1758*; Haaman's Kraal Railroad Station, alt. 3,389 ft. a ballast weed. Jan. 30, 1904, *Davy 1095*; Pretoria, alt. 4,400 ft., an occasional garden weed (escaped from a lawn?), March, 1904, *Davy*. In Durban it is sometimes used for lawns; in the Southern United States it is usually found in cultivated fields, often in such abundance as to displace the less vigorous native grasses, and it is sometimes cut for hay, *Scribner*. Though an annual grass it is said to be valued for pasture in Australia. *Hackel*



states that in parts of Africa a decoction is prepared from the seeds, which is used for inflammation of the kidneys.

*Eleusine indica* (L.) Gaertn. Fruct. 1 : 8. GOOSE-GRASS, Chiendent patte de poules. Native of the tropics of the Old World; probably introduced in the new world, *Stapf*. Natal, a troublesome weed, growing very rank under favourable conditions, *J. M. Wood*. In the Transvaal it is a troublesome weed of gardens, roadsides and cultivated lands; it roots deeply and holds tenaciously to the soil:—Johannesburg, E.S.C. A. Herb. 307 teste *Stapf*.; Potchefstroom, alt. 4,500 ft., a common roadside weed, Jan. 23, 1904, *Davy 1058*; Pretoria, alt. 4,400 ft., common roadside, garden and farm weed, Jan. 16, 1904, *Davy 1039*; Warm Baths, alt. 3,524 ft., a common weed in cultivated ground, Jan. 31, 1904, *Davy 1142*; Waterval Boven, alt. 4,826 ft., common weed on railway ballast heaps, Feb. 4, 1904, *Davy 1432*; Schweizer Reneke, a common roadside weed, Feb. 18, 1904, *Davy 1674*; Standerton, a small patch on the farm Beginsel, introduced with manure or forage, March 29, 1904; Belfast, alt. 6,400 ft., a garden and roadside weed, Feb. 5, 1904, *Davy 1264*; Irene, alt. 4,800 ft. a common weed, Feb. 25, 1904.

*Eragrostis minor megastachya* (Link) *Davy* in *Jepson Flor. Midd.-West Calif.* 60 (1901) (*E. major*, Host). STINK-GRASS. Native of the Mediterranean region and India; probably introduced in S. Africa, *Stapf*; spread through the two warmer zones of both hemispheres, *Baker*. Only occasional in the Transvaal: Near Lydenburg, *Atherstone*; Warm Baths, a common weed in cultivated ground, Jan. 31, 1904, *Davy 1143* and March 7, 1904, *Davy 1704*; Standerton, alt. 5,000 ft., an occasional weed, March 28, 1904, *Davy 1782*.

*Lolium temulentum*, Linn. Sp. Pl. 83 (1753). DARNEL, Cheat. Native of Europe, N. Africa, W. Siberia, and India; *Hook. f.* introduced in N. America, S. Africa, etc., a colonist in England, *Wats.* Adventive in the Transvaal, in grain-fields, etc. Matebe Valley, *Holub*; Potchefstroom, alt. 4,500 ft., naturalised on roadsides, Dec. 27, 1903, *Davy 852*, and in oat stubble, Oct. 10, 1903, *Davy 1762*; Pretoria, alt. 4,400 ft., an occasional weed, March, 1904. The grain ("seed") is very poisonous.

*Lolium temulentum arvense* (With.) Syme. BEARDLESS DARNEL, Beardless cheat. Distribution, same as that of the species? Potchefstroom, alt. 4,500 ft., in oat stubble, less common than the species, Oct. 10, 1903, *Davy 1763*; Pretoria, alt. 4,400 ft., an occasional weed, March, 1904.

*Panicum helopus glabrescens*, K. Schum. in *Engl. Pfl. Ost. Afr. C.* 101. Native of East Africa, Abyssinia, the Mascarene Islands, and India: reported from Natal, the Orange River Colony, and the plains near Queenstown at an altitude of 3,500 ft. A troublesome annual weed of cultivated land in the Transvaal:—Pretoria, alt. 4,400 ft., a common and troublesome weed, Dec. 16, 1903, *Davy 789*, and at Hartebeeste-nek, Nov. 14, 1903, *Davy 785*; Standerton, alt. 5,000 ft., a common weed by

roadsides and in gardens, Jan. 5, 1904, *Davy* 906; Haaman's Kraal Railroad Station, alt. 3,389 ft., a ballast weed, Jan. 30, 1904, *Davy* 1094. Seeds profusely, the grain ripening and falling irregularly.

*Panicum isachne*, Roth ex Rœm. and Schult. Syst. 2: 458; Nov. Pl. Sp. 54. Native of the Mediterranean region, Abyssinia and India; found also in Natal, Basutoland, the Transkei and Bechuanaland. In the Transvaal it is a troublesome weed of cultivated lands, difficult to eradicate, as it roots at the nodes, and the internodes break easily when it is hoed or pulled, leaving the nodes ("joints") to form new plants:—Pretoria, alt. 4,400 ft., a common and troublesome weed, Dec., 1903, *Davy* 790; Skinner's Court, common in wet black loam, Dec., 1903, *Davy* 793; Waterval Boven, alt. 4,826 ft., an occasional weed, Feb. 4, 1904, *Davy* 1444; Belfast, a garden weed at farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy* 1259; Standerton, alt. 5,000 ft., a common roadside weed, Jan. 5, 1904, *Davy* 897; a garden weed at farm Beginsel, March 29, 1904, *Davy* 1793.

*Paspalum dilatatum*, Poir., Encycl. 5: 35. LARGE WATER-GRASS, Breedzaad. Native of Brazil; naturalised (apparently) in the S.E. United States; an alien in Australia and S. Africa. Cultivated for pasture in Australia and (experimentally) in Natal, the Orange River Colony, and the Transvaal:—Lydenburg, well established near the spruit, June 16, 1903, *Davy* 408; Pretoria, alt. 4,400 ft., well-established and spreading rapidly in moist soils, along the Aapies River and near water-furrows in the lower parts of town, Dec. 1903, *Davy* 788. Considered an excellent pasture grass, and when well established enduring seasons of excessive drought without injury. It is particularly valuable as furnishing excellent late summer and autumn feed, during which period it makes its principal growth, *Scribner*.

*Pennisetum spicatum* (Willd.) Rœm. and Schult. Syst. 2 499. PEARL-MILLET, Cat-tail millet, Leeuja (Sesutu), Umvelli-velli (Matabele). Native of Tropical Africa (and India?); cultivated in numerous forms in Tropical Africa and India, for its grain; and in the United States for forage; in S. Africa it appears to occur only as a cultivated crop or as an escape. Stapf cites the following collections:—"In Mr. Hesse's garden at Cape Town, brought from Inhambane," *Burchell*; in Tabana's gardens, Cave Mountains, Transvaal, *Nelson*, 38; near Durban, *Drège*; Delagoa Bay, *Scott*; Orange River Colony, *Cooper*. In the Transvaal I have only seen it as a cultivated crop:—Springbok Flats, cultivated by the natives for the preparation of Kaffir beer, March 6, 1904, *Davy* 1724.

*Phalaris canariensis*, Linn., Sp. Pl. 54 (1753) CANARY-GRASS. Native of warm and temperate Europe, N. Africa, and W. Asia; introduced in N. America; an escape in fields and waste places in Britain, *Hook. f.* Pretoria, alt. 4,400 ft., accidentally introduced with grass and other forage plant seeds, brought by the writer, from California, in May, 1903; Skinner's



Court, Nov., 1903, *Davy* 792. Scarcely likely to become naturalised in the Transvaal.

*Phalaris minor*, Retz. Obs. 3 : 8. SMALL CANARY-GRASS. Native of the eastern Mediterranean region, Greece, the Orient, etc.; introduced in many other parts of the world; naturalised in the coast region of S. Africa, and in Tembuland, 4,000 ft. alt., *Stapf*. Pretoria, alt. 4,400 ft., accidentally introduced with grass and other forage plant seeds, brought by the writer, from California, in May, 1903, Skinner's Court, Nov., 1903.

*Phleum pratense*, Linn., Sp. Pl. 59 (1753). TIMOTHY. Timothy-grass. Native of Europe, N. Africa, Siberia and W. Asia; ascends to 1,400 ft. in the north of England, *Hook. f.*; cultivated as a hay crop in most humid temperate regions, and often found as an escape. In the Transvaal I have only found it spontaneous once:—Near Nylstroom, a farm escape, Nov., 1903.

*Poa annua*, Linn., Sp. Pl. 68 (1753). WALK-GRASS. Native of north temperate Europe (Arctic), Asia and N. Africa; ascends to 3,200 ft. in the Highlands of Scotland; doubtfully indigenous in N. America, *Hook. f.* A common weed of garden walks in England, California, etc. In the Transvaal it is adventive, but does not appear to colonise readily:—Lydenburg, in moist, shady places by the water-furrow on the main street, June 15, 1903, *Davy* 401; Potchefstroom, alt. 4,500 ft., on garden paths and along water-furrows, occasional, Dec. 27, 1903, *Davy* 1034; Belfast, alt. 6,446 ft., at foot of water tank at the railway station, Feb. 7, 1904, *Davy* 1390; Pretoria, alt. 4,400 ft., foot of a damp, shaded wall, March 16, 1904, *Davy* 1750; Johannesburg, shady garden walk near Rissik Street, April, 1904.

*Rotthoellia compressa fasciculata*, Hack. Androp. in DC. Monogr. Phan. 6 : 286. Found throughout the warm countries of both hemispheres, in many localities, evidently introduced; the species occurs throughout India and south-west China, *Stapf*. In S. Africa only the variety is known to occur; it has been collected in Cape Colony, Natal and the Transvaal, and may be indigenous here:—Pretoria, alt. 4,400 ft., common in marshy ground at Skinner's Court, Dec. 1903; Belfast, alt. 6,400 ft., common on the borders of pans containing stagnant water, Feb. 5, 1904, *Davy* 1279; Standerton, common on the borders of stagnant vleis, March, 1904.

*Setaria verticillata*, Beauv., Agrost. 51. BRISTLY FOXTAIL, Klits-gras. Probably native of Europe; but now widely distributed throughout the tropical and warmer temperate regions of the world, as a weed in cultivated ground; naturalised in the Eastern United States, etc. Near Lydenburg, *Atherstone*, *Wilms* 1670; Zoutspansberg, *Nelson* 16; Pretoria, alt. 4,400 ft., a weed in yards and cultivated ground, Jan. 16, 1904, *Davy* 1040; Hartebeeste-nek, an orchard weed, Nov. 14, 1903, *Davy* 757; Warm Baths, alt. 3,500 ft., a roadside weed, Nov., 1903; Belfast, a garden weed, farm Rietvlei, alt. 6,000 ft., Feb. 5,

1904, *Davy* 1257; Klerksdorp, an orchard weed at farm Jakhalsfontein, Feb., 1904. Our plant does not appear to be identical with the European form, and is possibly the one referred to by some authors under the specific name *Aparine*, which may be indigenous to tropical Africa.

*Tragus racemosus*, Scop. Introd. 73; All. Fl. Pedem. 2: 241. CARROT-SEED GRASS, Prickle-grass. Native of the Mediterranean region; also found in Afghanistan; now a common weed in most warm countries of both hemispheres, and widely distributed in S. Africa, being found in the Coast, Central and Kalahari regions of Cape Colony, in Natal and at Delagoa Bay. In the Transvaal it is a common weed in vacant erven in towns, along roadsides and near farmsteads; Barberton, a weed along the railway track at Avoca Station, June 8, 1903, *Davy* 241; Schweizer Reneke, occasional by roadsides, Homan's Vlei, Feb. 17, 1904, *Davy* 1658. The hooked prickles on the glumes enable the fruits to adhere readily to the hair and wool of animals and the clothing of man, thus aiding their dissemination. They may prove somewhat injurious to wool and mohair.

*Tricholæna rosea*, Nees, Cat. Sem. Hort. Vratisl., 1835 and in Linnæa 11: Lit. Ber. 129 in part; Fl. Afr. Austr. 1: 17 in part. NATAL RED-TOP GRASS, um-Kuana. Native of Tropical Africa, Madagascar and southern Arabia; common almost throughout South Africa. Barberton, common along roadsides and in old maize fields ("mealie-patches") or other cultivated grounds, June 9, 1903, *Davy* 268. Probably indigenous in the Low-country of the Transvaal, but apparently an alien on the High Veldt, where it seems to be most abundant along old trek roads.

#### Family LABIATÆ: Mint Family.

*Leucas martinicensis* (Swartz) R.Br. Prodr. 504. Probably of Asiatic origin, but now a common tropical plant; occurs in Senegal and Guinea, *Hook*; Angola, plentiful in neglected fields near Lopollo, *Welwitsch*; naturalised in Natal, *Harvey*, from 1,000 to 2,000 ft. alt., *J. M. Wood*. Evidently an alien in the Transvaal:—Waterval Boven, alt. 4,826 ft., Feb. 4, 1904, a common weed in the village, *Davy* 1454; Belfast, a single specimen at farm Rietvlei, alt. 6,000 ft., Feb. 1904; Schweizer Reneke, a few plants on farm Biessieslaagte, Feb. 18, 1904, *Davy* 1688.

*Mentha aquatica*, Linn., Sp. Pl. 576 (1753). WATER-MINT. Native of Europe, Asia and N. Africa. Found in Natal from sea-level up to 2,000 ft. alt., *J. M. Wood*. Occasional in the Transvaal:—Pretoria, along the Aapjies River, alt. 4,400 ft., Jan. 28, 1904, *Davy* 1077.

*Salvia obtusata*, Thunb. Prodr. Pl. Cap. 97. Native of S. Africa, but apparently an alien in the Transvaal, where it occurs as a roadside weed in villages:—Pretoria, alt. 4,400 ft., Nov. 12, 1893, *Schlechter* 3691 in Herb. Natal; Fourteen

Streams, a common ballast weed on the railway, Feb. 14, 1904, *Davy 1556*.

*Salvia* sp. A white-flowered species which I have not yet been able to identify, is a common weed around towns and villages and at outspan places and farmsteads, having all the appearance of an alien. It is particularly abundant near Bloemhof and Christiana, where it is a characteristic weed, covering large areas of town commonage.

Family LEGUMINOSÆ: Pea and Bean Family.

*Acacia decurrens*, Willd., Sp. Pl. 4 : 1072. BLACK WATTLE. Native of New South Wales; extensively cultivated in Natal for tan-bark, and grown experimentally in many places on the High Veld of the Transvaal:—Lydenburg, spontaneous on Sterk-hill, by the roadside above the block-houses, some miles from town, June, 1903; Florida, alt. cir. 5,700 ft., spontaneous along the railway and near plantations, March 25, 1904.

*Casalpinia sepiaria*, Roxb. Hort. Beng. 32; Fl. Ind. 2 : 360. MAURITIUS THORN, Mysore Thorn, Cassie, Sappan liane. Native of S.E. Asia east to Japan; Burmah, China and India; ascends to 4,000 ft. *Collett*. Frequently cultivated as a hedge plant in tropical and sub-tropical countries:—Barberton, planted for hedges and now naturalised, June 9, 1903, *Davy 279*. It furnishes a red dye-wood; can advantageously be planted along with *Pterolobium lacerans*, R.Br., for hedges, *Mueller*.

*Erythrina caffra*, Thunb. Prodr. Pl. Cap. 121. CAPE KAFFIR-BOOM. Native of Cape Colony and Natal, from sea-level to 4,000 ft. alt., *J. M. Wood*. Cultivated in Pretoria as an ornamental tree, and two specimens are naturalised on Meintjes Kop, Arcadia, above the Ziervogel quarry, near the site of an old kraal, Aug. 2, 1903, *Davy 615, 1777*.

*Medicago denticulata*, Willd. Sp. Pl. 3 : 1414. Native of Middle and Southern Europe, N. Africa, N. Asia and India; naturalised in N. America, *Hook. f.*, one of the commonest alien weeds in California. In 1862 it was already found in sandy places near Cape Town, Hottentots Holland and Paarl, *Flora Capensis*; in Natal it is found from 3,000 to 4,000 ft. alt., *J. M. Wood*. Only occasional in the Transvaal, where it does not appear to take kindly to the climate:—Lydenburg, a single specimen on the footpath in front of the Club, June 16, 1903, *Davy 420*; Middelburg, a single specimen on the site of an old camp near the Cemetery, June, 1903; Pretoria, alt. 4,400 ft., a single specimen at Skinner's Court, Nov. 1903; Potchefstroom, alt. 4,500 ft., occasional near the Repatriation Camp, Dec. 27, 1903, *Davy 1770*; Waterval Boven, alt. 4,826 ft., a single specimen by the roadside in the village, Feb. 4, 1904, *Davy 1455*. The seeds contain oil, and the dry, ripe burrs give valuable autumn and winter feed for

cattle, being highly nutritious and fattening; they are very injurious to wool, however.

*Medicago sativa*, Linn., Sp. Pl. 778 (1753). LUCERNE, Alfalfa, Purple medic. Native of the Eastern Mediterranean region; naturalised elsewhere, *Hook. f.*; now cultivated in most arid warm-temperate countries, where it is often the principal forage crop; frequently found as a farm escape:—Standerton, a casual escape in the garden of Beginsel, March 30, 1904, *Davy 1803*.

*Trifolium hybridum*, Linn., Sp. Pl. 766 (1753). ALSIKE CLOVER. Native of the Mediterranean region; a valuable forage-plant, frequently cultivated in warm-temperate countries, and occasionally found as a farm escape:—Pretoria, alt. 4,400 ft., an escape at Daspoort, a single specimen, Jan. 28, 1904, *Davy 1178*; Potchefstroom, alt. 4,500 ft., a few stray specimens along the irrigation furrow, Jan., 1904.

*Trifolium pratense perenne*, Agric., Percival, Agric. Bot. 404 (1900). Cow-CLOVER, Cow-grass, Perennial red-clover. Native of Europe (Arctic), N. and W. Asia; ascends to 1,300 ft. in the Scotch Highlands; introduced in N. America, *Hook. f.* A valuable forage plant, more extensively cultivated, in humid temperate climates, than any other clover; occasional as a farm-escape: Standerton, alt. 5,000 ft., a solitary plant naturalised on the bank of the spruit, on rich black loam, Jan. 5, 1904, *Davy 892*; Belfast, alt. 6,446 ft., a single specimen on railway ballast, with *Capsella*, *Spergula*, *Poa annua*, etc., Feb. 7, 1904, *Davy 1393*.

*Vicia sativa*, Linn., Sp. Pl. 736 (1753). COMMON VETCH, Tares. Native of the Mediterranean region; cultivated in Europe, Asia, and America for forage; naturalised in the Northern United States and South Africa. Found in Natal, as an alien, between 2,000 and 3,000 ft. alt., *J. M. Wood*. It appears to take readily to the climate of the Transvaal: Potchefstroom, alt. cir. 4,500 ft., freely naturalised at Haaskraal, Oct. 10, 1903, *Davy 1766*; near Nylstroom, Nov. 1903, a farm escape.

#### Family MALVACEÆ: Mallow Family.

*Gossypium herbaceum*, Linn., Sp. Pl. 693 (1753). COMMON COTTON, Wild cotton, Upland cotton, Cotonier. Native of Tropical Asia; the wild form exists in Scinde and Cabul, *Oliver*; cultivated in almost every district of Tropical Africa, *Oliver*; grown for cotton in various parts of India, Japan, the United States, Southern Europe, etc. Not uncommon in the Low country of the Transvaal:—Komatipoort, occasional in the bush near the village, June 12, 1903, *Davy 359*; near Barberton, alt. 500 ft., Jan. 1904, *Legge 39* in Herb. Natal; specimens have also been received from Leydsdorp and other places in the Zoutpansberg District.

*Hibiscus trionum hispidus*, DC., Prodr. 1 : 453. BLACK-

**EYED SUSAN.** Original home uncertain, now a common weed of most tropical and sub-tropical countries, often cultivated in gardens as an ornamental annual. In Natal it is found from sea-level up to 3,000 ft. alt., *J. M. Wood*. A common weed of cultivated lands in the Transvaal:—Pretoria, alt. 4,400 ft., a common garden weed, Dec. 13, 1903, *Davy* 798; Belfast, a garden weed at farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy* 1266.

*Malva parviflora*, Linn., Diss. Dem. Pl. Nov.; Amœn. Acad. **3** : 416. **SMALL-FLOWERED MALLOW.** Native of the Mediterranean region; introduced with ballast into England, *Hook. f.*; abundantly naturalised in California; in 1860 reported as an introduced weed on roadsides and in waste places in Cape Colony. Only occasional in the Transvaal:—Lydenburg, an occasional garden weed, June 15, 1903, *Davy* 397; Potchefstroom, alt. 4,500 ft., a roadside weed, Dec. 27, 1903, *Davy* 853, 1035; Bloemhof, alt. cir. 4,100 ft., a common weed on vacant erven, Feb. 11, 1904, *Davy* 1511; Fourteen Streams, a garden weed, Feb. 14, 1904, *Davy* 1602.

*Sida rhombifolia*, Linn., Sp. Pl. 684 (1753). **SIDA**, Pretoria weed, Pretoria bosjie. Native land uncertain; now a common weed of agriculture throughout the tropics and warmer temperate zones of both hemispheres; reported from the Eastern Districts of Cape Colony and from Port Natal as early as 1860; occurring in Natal below 2,000 ft. alt., *J. M. Wood*. Abundant in almost all the towns and villages of the Transvaal from Zeerust to Barberton and Komatie-poort; one of the most prominent and unsightly weeds in the borders of cultivated gardens and on vacant erven:—Lydenburg, a weed on vacant erven, but not as plentiful as in Pretoria, June 16, 1903, *Davy* 418; Pretoria, Zeerust, Rustenburg, Barberton, Komatie-poort, etc.

Family **MELIACEÆ**: Seringa Family.

*Melia azedarach*, Linn., Sp. Pl. 384 (1753). **BEAD-TREE**, Cape lilac, Indian lilac, Pride of India, Pride of China, China berry-tree, Chinese wax-berry, Tame seringa, Holy tree, Arbre à chapelet, Lilas de l'Inde. Native of the Himalaya region of northern India, and Persia; now cultivated in almost all warm countries for ornament, shade, and for the sake of its wood; frequently escaped from cultivation in warm countries. Natal, naturalised as an escape below 2,000 ft. alt., and become a nuisance in several places, *J. M. Wood*. Widely grown in the Transvaal as a shade tree, and occasionally met with as an escape:—Pretoria, semi-spontaneous as an escape at Daspoort, Dec. 1903. The berries are supposed to be poisonous.

Family **MORACEÆ**: Mulberry Family.

*Cannabis indica*, Lam. Encyc. **1** : 695. **DAGGA**, Insangu, Indian hemp. Native of the N.W. Himalaya and Central Asia; extensively cultivated in India. Introduced into S.

Africa, and now widely distributed as a garden weed; cultivated sparingly by the natives under the name of Insangu for the sake of its leaves (bhang) and pistillate flowers, which are smoked by them; carefully preserved by the Kaffirs wherever found; it occurs as an escape in almost every town and village in the Transvaal, and in farm gardens:—Lichtenburg, a garden weed, May 18, 1903, *Davy* 56; Barberton, June, 1903; Potchefstroom, a common escape on vacant erven, March 25, 1904; Standerton, a casual in the old garden on farm Beginsel, March 29, 1904, *Davy* 1806.

Family MYRTACEÆ: Eucalyptus Family.

*Eucalyptus globulus*, Labill., Voy. 1 : 153, t. 13; Nov. Holl. Pl. 2 : 121. BLUE-GUM. Native of Victoria and Tasmania; extensively cultivated in the Mediterranean region, California, and S. Africa as a windbreak, to drain unhealthy low-lands, for fuel, and for its leaves, from which Eucalyptus oil and Eucalyptol are distilled. Now semi-spontaneous in the Transvaal from self-sown seeds on the borders of plantations, etc.:—Langlaagte, spontaneous in and near plantations, March 25, 1904.

Family NYCTAGINACEÆ: Four o'clock Family.

*Mirabilis jalapa*, Linn., Sp. Pl. 177 (1753). FOUR O'CLOCK, Marvel of Peru, Belle de nuit. Native of Tropical America. Frequently cultivated in flower-gardens and often occurring as a garden escape:—Belfast, a garden escape at farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy* 1252.

Family ONAGRACEÆ: Evening-primrose Family.

*Oenothera biennis grandiflora*, Lindl. EVENING-PRIMROSE. Native of N. America; less common in the Eastern United States than the species, *Gray*. Frequently cultivated in gardens as an ornamental, and often found as a garden escape; occasional in the Transvaal:—Belfast, a garden escape at farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy* 1248; Belfast, alt. 6,400 ft., a solitary specimen on the roadside towards the Dingaan monument, Feb. 6, 1904, *Davy* 1325, a form with entire and very rigid leaves.

*Xylopleurum roseum* (Ait.) Raim. Native of the south-western United States (and Mexico?), Texas, and New Mexico southward. Offered by seedsmen, and often cultivated in gardens; frequently found as an escape. An alien in Natal from 2,000 to 3,000 ft. alt., *J. M. Wood*. Potchefstroom, 4,500 ft. alt., not uncommon as a roadside weed, Dec. 27, 1904, *Davy* 1038.

*Xylopleurum tetrapterum* (Cav.) Raim. Native of the south-western United States (and Mexico?), Texas and southward. Often cultivated in gardens as an ornamental; the flowers open in the evening and are fragrant, pure white, changing to pink in drying. Pretoria, alt. 4,400 ft., a roadside weed near the



Park, Dec. 20, 1903, *Davy 1776, 1778*; Potchefstroom, alt. 4,500 ft., a common roadside weed near the Park, Dec. 27, 1904, *Davy 857*.

Family OXALIDACEÆ: Sorrel Family.

*Oxalis corniculata*, Linn., Sp. Pl. 435 (1753). YELLOW SORREL. Original home probably S. Europe; now "ubiquitous except in very cold regions," *Hook. f.* In 1862 it was recorded as occurring "everywhere in cultivated ground throughout Cape Colony and in Kaffraria," *Flor. Cap.* Natal, below 2,000 ft. alt., *J. M. Wood*. A common town weed in the Transvaal, in gardens and by roadsides:—Pretoria, 4,400 ft. alt., a common weed by roadsides and in gardens, on lawns, beside walks, in flower-beds, March 20, 1904, *Davy 1779*. My specimens appear to connect with *O. stricta*, L.; they produce runners, but the plant is pubescent and the capsules are downy.

*Oxalis* sp. A species with rosy flowers is a common weed in cultivated ground in several parts of the Transvaal:—Lydenburg, a common weed in low cultivated ground near the spruit. June 16, 1903, *Davy 419*.

Family PAPAVERACEÆ: Poppy Family.

*Argemone mexicana ochroleuca*, Lindl. MEXICAN POPPY. Texas poppy, Chardon du pays; in S. Africa sometimes mis-called "Scotch thistle"; it is not a thistle, and the true Scotch thistle is a very different plant. Native of Tropical America; naturalised in the United States and South Africa. A troublesome weed in Cape Colony, where it has been proclaimed a noxious weed under the Burweed Act. Adventive in the Transvaal:—Pretoria, a roadside weed near the Daspoort oil-mills, and near the cemetery, Jan. 28, 1904, *Davy 1073, 1176*; Bloemhof, alt. 4,100 ft., a common weed, Feb. 12, 1904, *Davy 1505*; Karree-pan, between Bloemhof and Christiana, occasional, Feb. 12, 1904, *Davy 1501*; Christiana, Feb. 16, 1904; Fourteen Streams, a common weed, Feb. 14, 1904, *Davy 1549*. The typical form, with bright yellow flowers, occurs in Natal along the coast at Durban.

Family PEDALIACEÆ: Sesamum Family.

*Sesamum indicum*, Linn., Sp. Pl. 634 (1753). SESAME, Thunderbolt flower, Gingili. Originally from the Sunda Islands, *A. de Candolle*, now found throughout southern Asia, eastward to Japan; Schweinfurth considered that it might also be indigenous to Central Africa. Extensively cultivated in India, Siam, Japan, Turkey, German East Africa, etc., for the sake of the seeds, from which a valuable non-drying oil is expressed, which is *the* oil of India, and which is used as a substitute for Olive oil and for soap-making; the soot obtained from burning the oil is said to be used in the preparation of some kinds of Chinese ink. It occurs as an alien in Natal, from sea-level to 1,000 ft. alt., *J. M. Wood*. Barberton, a weed in Tur-

ton's orchard, eight miles west of town, June 9, 1903, *Davy* 250: Sheba road, April 1904, *Thorncroft* 577, in Herb. Natal.

Family PLANTAGINACEÆ: Lamb's-tongue Family.

*Plantago lanceolata*, Linn., Sp. Pl. 113 (1753). LAMB'S-TONGUE, Ribwort. Native of Europe, N. Africa, N. and W. Asia, and the Himalaya; an alien in N. America and S. Africa; ascends to 2,200 ft. in the Scotch Highlands, *Hook. f.* Found in Natal from 3,000 to 4,000 ft. alt., *J. M. Wood*. The leaves are said to be used in Scotland for dressing sores. Adventive in the Transvaal, and apparently taking kindly to the climate:—Pretoria, alt. 4,400 ft., a common roadside weed, Nov. 29, 1903, *Davy* 821; Potchefstroom, alt. 4,500 ft., a common roadside weed, Dec. 27, 1903, *Davy* 1768; Warm Baths, alt. 3,500 ft., a farm weed, March 7, 1904, *Davy* 1710.

*Plantago major*, Linn., Sp. Pl. 112 (1753). WILD PLANTAIN. Native of Europe, N. Africa, N. and W. Asia, and the Himalaya; an alien in N. America and S. Africa; ascends to 2,000 ft. in Northumberland, *Hook. f.* Seeds used for feeding cage-birds. Reported from Natal, *J. M. Wood*. An adventive roadside weed in the Transvaal, in moist, shady places:—Potchefstroom, alt. 4,500 ft., a roadside and garden weed, along water-furrows, Dec. 28, 1903, *Davy* 1183; Haaskraal, a garden weed, Jan., 1904, *Davy* 1217; Christiana, alt. 4,100 ft., Feb. 16, 1904, *Davy* 1621.

Family POLYGONACEÆ: Dock Family.

*Polygonum amphibium*, Linn., Sp. Pl. 361 (1753). WATER PERSICARIA. Native of the North-temperate zone. Standerton, common in stagnant water of vleis on farm Beginsel, alt. 5,300 ft., May 31, 1904, *Davy* 1808.

*Polygonum aviculare erectum* (Linn.) Roth. UPRIGHT KNOT-WEED, Upright wire-weed, Upright yard-weed. Native of Europe; an alien in N. America and Africa. Adventive in the Transvaal:—Potchefstroom, alt. 4,500 ft., a common weed at Haaskraal, Dec. 27, 1903, *Davy* 1771; Standerton, alt. 5,000 ft., a common street weed, Jan. 5, 1904, *Davy* 904; Belfast, a garden weed at farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy* 1256. Differs from typical *P. aviculare*, Linn. in its more erect habit, yellowish colour, larger flowers, and 5 or 6 instead of 8 stamens; the leaves are usually larger and more obtuse.

*Polygonum convolvulus*, Linn., Sp. Pl. 364 (1753). BLACK BINDWEED, Climbing buckwheat, Bearbine. Native of the North-temperate and Arctic regions; an alien in America, *Hook. f.*; adventive in the Transvaal:—Potchefstroom, alt. 4,500 ft., a solitary specimen among oat stubble, Jan. 24, 1904, *Davy* 1213, a few specimens in the Experiment plots, March 24, 1904; Standerton, a few specimens in a maize-patch, farm Beginsel, March 29, 1904, *Davy* 1785.

*Polygonum lapathifolium maculatum* (Krock) *Hook. f.* SPOTTED KNOTWEED. Native of Europe. Pretoria, 4,400 ft.,



common along the Aapies River, by pools, furrows, and slowly moving water, Jan. 4, 1904, *Davy* 835; Standerton, alt. 5,000 ft., common beside vleis, Jan. 5, 1904, *Davy* 905; Christiana, alt. cir. 4,100 ft., common along ditches, Feb. 15, 1904, *Davy* 1617.

*Rumex acetosella*, Linn., Sp. Pl. 538 (1753). SOUR DOCK, Sorrel, Sheep's sorrel. Native of the North-temperate and Arctic zones of Europe and Asia; an alien in N. America and the Southern hemisphere; ascends to 2,500 ft. in Yorkshire, *Hook. f.* Adventive in the Transvaal and spreading both in cultivated ground and on the open veldt:—Pretoria, alt. 4,400 ft., a few plants in a plot of Australian Saltbush, at Skinner's Court, Feb. 1, 1904, *Davy* 1190; Pretoria, spreading in town, March 26, 1904; Belfast, alt. 6,400 ft., well established in waste places in the village, also a few plants beside the water-tank at the railway station, and a large patch between the station and the village, not far from the Repatriation Camp site, where it appears to be crowding out the native grasses, Feb. 5, 1904, *Davy* 1373, 1465; Potchefstroom, alt. 4,500 ft., a few specimens in an oat-stubble field, Feb. 21, 1904; Standerton, alt. cir. 5,300 ft., naturalised in an old garden on farm Beginsel, March 29, 1904, *Davy* 1797. A pernicious weed of garden, farm, and veld if well established; spreading both by seed and by underground running stems.

*Rumex crispus*, Linn., Sp. Pl. 335 (1753). CURLY DOCK. Native of Europe, an alien in N. America and S. Africa. Adventive in the Transvaal:—Pretoria, alt. 4,400 ft., naturalised in low ground along the Aapies River, Jan. 3, 1904, *Davy* 833. Our plant appears to be the variety *trigranulata*, Syme.

*Rumex ecklonianus*, Meisn., in Linnæa 14: 493 (1840). ECKLON'S DOCK. A native of Cape Colony. Common along roads and spruits in towns and villages of the Transvaal, where it may be indigenous though it has the aspect of an alien:—Standerton, alt. 5,000 ft., common along the vlei and on town streets, Jan. 5, 1904, *Davy* 903; Bloemhof, occasional, but not common, by roadsides near Rietfontein, Feb. 11, 1904, *Davy* 1526.

#### Family PORTULACACEÆ: Purslane Family.

*Portulaca oleracea*, Linn., Sp. Pl. 445 (1753). COMMON PURSLANE. Native of S. Europe, now widely distributed through the warmer regions of the globe; an alien in the United States and S. Africa. Reported as occurring in cultivated and waste ground at the Cape as early as 1865. In Natal it is found below 2,000 ft. alt., *J. M. Wood*. A common and widely distributed weed of cultivated land in the Transvaal, and evidently here to stay; often injuriously affected by a fungus disease:—Pretoria, a common garden and orchard weed, Hartebeeste-nek, Nov. 14, 1903. *Davy* 761; Pretoria, alt. 4,400 ft., a common weed in town gardens, Dec. 13, 1903; Ermelo, in the shade of

fruit trees, badly diseased, Jan. 8, 1904, *Davy* 972; Haaman's Kraal Railway Station, alt. 3,380 ft., a ballast weed, Jan. 30, 1904, *Davy* 1101; Schweizer Reneke, an occasional farm-yard weed, Vierfontein, Feb. 17, 1904, *Davy* 1632. It is good for salad, and is also used as a pot-herb, *Hook. f.*

Family PRIMULACEÆ: Pimpernel Family.

*Anagallis cœrulea*, Lam., Fl. Fr. ed. 1, **2** : 285. BLUE PIMPERNEL. Native of southern Europe. A casual, not yet established in the Transvaal:—Pretoria, a few plants at Skinner's Court, Oct., 1903, perhaps introduced with seeds of forage plants from California. The common red pimpernel, *Anagallis arvensis* has not yet been reported, but is almost sure to appear sooner or later.

Family ROSACEÆ: Rose Family.

*Prunus persica*, Stokes, Bot. Mat. Med. **3** : 100. PEACH, Perske. Native of China, not really indigenous to Persia, *De Candolle*; cultivated in almost all warm-temperate countries. Grown by almost every farmer in the Transvaal, readily growing from self-sown seed and not infrequently found as a spontaneous escape from cultivation:—Pretoria, an escape at the Fountains, Oct., 1903, *Davy* 1775.

*Rubus rosæfolius*, Smith, Pl. Ic. Ined. **3** : t. 60. STRAWBERRY-RASPBERRY; locally known as the New Zealand raspberry. Native of the Himalaya region and eastward to China and Japan; naturalised in Australia and other sub-tropical and tropical countries. Frequently cultivated as an ornamental plant; the fruits, though edible, are insipid. Ecklon and Zeyher collected it on the "sides of Table Mountain, facing the town," *Fl. Cap.* Occasionally cultivated in the Transvaal, and once met with as a garden escape:—Barberton, a garden escape in the Moody Concession, June 9, 1903, *Davy* 262.

Family SALICACEÆ: Willow Family.

*Populus alba canescens*, Loudon. WHITE POPLAR, Abele. Native of Europe and northern Asia. Extensively grown around farmsteads throughout the Transvaal, and cut for poles and for rafters to support thatch-roofs; occasionally escaped from cultivation and established along streams:—Crocodile River, at the Magaliesberg, spontaneous along the river, May 30, 1903, *Davy* 188; Roodepoort, spontaneous near the railway, March 26, 1904.

*Salix babylonica*, Linn., Sp. Pl. 1017 (1753). WEEPING WILLOW, Wilge-boom. Native of the Caucasus and northern Asia. Grown around fountains and on dams almost throughout the Transvaal; occasionally sub-spontaneous, though I have not yet noticed any specimens growing from self-sown seed.

Family SCROPHULARIACEÆ: Witch-weed Family.

*Linaria vulgaris*, Mill., Gard. Dict. ed. 8. n.l. YELLOW TOAD-FLAX, Butter-and-eggs. Native of Europe (Arctic), the

Caucasus, and northern Asia; an alien in North America and S. Africa. A reputed purgative and diuretic. Sometimes cultivated in farm gardens in the Transvaal, and occasionally met with as an escape:—Ermelo, a garden escape, Jan. 8, 1904, *Davy* 974; Belfast, a garden escape at farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy* 1253.

*Veronica anagallis-aquatica*, Linn., Sp. Pl. 12 (1753). **BROOK-LIME.** Native of the North temperate zone. Occurs in Natal between 3,000 and 4,000 ft. alt., *J. M. Wood*. Pretoria, alt. 4,400 ft., occasional along a sluggish sluit, Dec. 13, 1903, *Davy* 799.

*Veronica Tournefortii*, C.C. Gmel. Fl. Bad. 1 : 39 (*V. persica*, Hort. ex. Poir Encycl. 8 : 542; *V. Buxbaumii*, Tenore, Fl. Nap. 1 : 7. t.l., teste *Index Kewensis*). **TOURNEFORT'S SPEEDWELL**, Buxbaum's speedwell. Native of Europe, from Belgium southward, N. Africa, W. Asia, the Himalaya; *Hook. f.* A colonist in Britain since 1825, *Wats.*; ascends to 1,000 ft. in Northumberland, *Hook. f.* An alien in N. America and S. Africa. Adventive in the Transvaal:—Lydenburg, a few specimens along a water-furrow in the main street, June 15, 1903, *Davy* 403.

#### Family SOLANACEÆ: Tobacco Family.

*Datura stramonium*, Linn., Sp. Pl. 179 (1753). **WHITE STRAMONIUM**, Stink-blaad, Common thorn-apple, Jamestown weed, Jimson weed, Feuille du diable, Herbe du diable. Probably of Asiatic origin; now almost cosmopolitan; an alien in Europe, the United States, and S. Africa. Natal, from sea-level up to 2,000 ft. alt., *J. M. Wood*. Abundantly distributed over the Transvaal, a common and troublesome weed in cultivated ground:—Belfast, a common garden weed at farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy* 1267; Kaalfontein Railroad Station, alt. 5,328 ft., a common weed, March 21, 1904. Contains *daturin*, a narcotic poison; the source of medicinal Stramonium. Valued locally as a remedy for asthma, neuralgia, and epilepsy.

*Datura tatula*, Linn., Sp. Pl. ed. 2. 256 (1762-3). **PURPLE STRAMONIUM**, Purple thorn-apple. Native of tropical America; an alien in the United States and S. Africa. A common weed of cultivated and waste ground, throughout the Transvaal, but seldom collected:—Potchefstroom, alt. 4,500 ft., common on vacant erven, March 25, 1904.

*Nicotiana glauca*, R. Graham, in Edinb. N. Phil. Journ. 175 (April-June, 1828); Bot. Mag. t. 2837. **TREE TOBACCO**, Mexican tobacco, Wilde tabac. Native of Argentina; an alien in the western United States and S. Africa. Abundant in parts of Natal and Cape Colony, about Kimberley and elsewhere. Said to have been carried by the Boers from Kimberley to the Vat River (Orange River Colony); thence to several places in the south-western Transvaal. Specimens have been

received from the vicinity of Potchefstroom; also reported from Christiana, where it is said to grow to a height of 15 to 20 ft. on the banks of the Vaal River and around homesteads. The leaves are said to be smoked by Mexican greasers; the plant is a narcotic poison, and is reported to have poisoned stock near Potchefstroom.

*Physalis minima*, Linn., Sp. Pl. 183 (1753). Probably a native of Tropical America; now widely distributed through the tropics as a weed. Pretoria, alt. 4,400 ft., a common weed on cultivated black loam (wet) at Skinner's Court, March 16, 1904, *Davy 1748*. Begins to flower in December. Related to the Cape gooseberry (*Physalis peruviana*); we have received fruits of what appears to be the latter species, under the name Leekomokomo, from the Zoutpansberg District, where they are eaten by the natives.

*Solanum incanum*, Linn., Sp. Pl. 188 (1753); Forsk. Fl. Ægypt.-Arab. 45. (*S. sanctum*, Linn., Sp. Pl. ed. 2. 269 teste *Index Kewensis*). Native of western Africa and eastern Asia. Near Barberton, alt. cir. 2,000 ft., Jan. 10, 1904, *Legge 49*, in Herb. Natal.

*Solanum sodomium*, Linn., Sp. Pl. 187 (1753). Var. ? Origin uncertain; now widely distributed in warm countries. Not uncommon as a weed on waste land in towns and villages through the Transvaal.

*Solanum nigrum*, Linn., Sp. Pl. 186 (1753). BLACK NIGHTSHADE. Origin uncertain; according to Hooker, it is now found in all temperate and tropical regions; in Natal it occurs from 1,000 to 2,000 ft. alt., *J. M. Wood*. A casual alien in the Transvaal, in gardens:—Belfast, a garden weed at farm Rietvlei, alt. 6,000 ft., Feb. 5, 1904, *Davy 1249*; Fourteen Streams, a garden weed, Feb. 14, 1903, *Davy 1592, 1604*; Pretoria, alt. 4,400 ft., a garden weed, March 16, 1904, *Davy 1752*; Potchefstroom, alt. 4,500 ft., a common garden weed, March 25, 1904; Standerton, a common garden weed, March 29, 1904, *Davy 1787, 1800*. Contains an alkaloid, *solanine*, which is a narcotic poison and a powerful local irritant.

*Solanum pseudo-capsicum*, Linn., Sp. Pl. 184 (1753). JERUSALEM CHERRY. Native of Madeira; much cultivated in greenhouses and windows in Europe and the United States. A garden escape in South Africa:—Lydenburg District, a casual garden escape near an old mine site, not far from the Mac Mac Falls, June 20, 1903, *Davy 437*; Potchefstroom, alt. 4,500 ft., a garden escape, Dec. 27, 1903, *Davy 855*. Contains *solanine*.

#### Family VERBENACEÆ: Verbena Family.

*Lantana salivifolia*, Jacq., Hort. Schoenb. 3 : 18. t. 285. PURPLE LANTANA, Uguguvama, Umpema (?). Native of Tropical Africa, India, and S. Africa, *Pearson*: found in Cape Colony, Natal, and the Transvaal. In Natal it occurs between 1,000

and 2,000 ft. alt., *J. M. Wood*. Eloff's Dam, near Pretoria, not abundant, apparently an alien, Nov. 9, 1903, *Davy 687*.

*Lippia asperifolia*, Rich., Cat. Hort. Med. Par. 67. Native of S. America. Barberton, a weed in cultivated ground, June 9, 1903, *Davy 273*, Jan., 1904, *Legge 27* (alt. cir. 2,500 ft.); Lydenburg, a weed on vacant erven, June 16, 1903, *Davy 417*.

*Verbena officinalis*, Linn., Sp. Pl. 20 (1753). VERVAIN. Native of Europe, from Denmark southward, N. Africa, W. Asia, and the Himalaya; an alien in N. America and S. Africa. Occurs in Natal between 1,000 and 2,000 ft. alt., *J. M. Wood*. A casual weed in the Transvaal:—On the Magaliesberg, *Burke 59*; near Lydenburg, *Wilms 1175*; near Pretoria, *Wilms 1175A*; Linokana, in the Marico District, *Holub* (teste *Pearson*); Lydenburg, a casual garden weed, June 15, 1903, *Davy 400*; Pretoria, alt. 4,400 ft., Dec. 31, 1903, *Davy 831*. An object of much superstition amongst the ancients, *Hook. f.*

#### Family ZYGOPHYLLACEÆ: Guaiacum Family.

*Tribulus terrestris hispidissimus* (Presl.) Sond. in Fl. Cap. 1 : 353 (1862). DEVIL'S THORNS, Duiwel's doorns. Origin uncertain; now widely distributed through the tropics. In the Transvaal it is a common weed in the western and northern districts, towns, in market-places and town lands, and at outspan places on main trek roads, also around homesteads and kraals:—Potchefstroom, alt. 4,500 ft., a common weed near the Repatriation Camp site, Dec. 27, 1903, *Davy 854*; Pretoria, alt., 4,400 ft., a roadside weed, not common, Jan. 4, 1904, *Davy 836*; Standerton, alt. 5,000 ft., sparingly met with on the village roads and vacant erven, Jan. 5, 1904, *Davy 901*; Fourteen Streams, a common weed, Feb. 14, 1904, *Davy 1545*; Schweizer Reneke, a common farmyard weed at Vierfontein, Feb. 18, 1904, *Davy 1662*; Warm Baths, alt. 3,500 ft., a common weed, Dec., 1903, *Davy 865*. The "burrs" are said to injure the feet of young lambs and kids, and to damage the wool of sheep.

#### Distribution of Species among Genera and Families.

There are in all 141 species enumerated in this list, representing 110 genera and 37 families.

Sixteen (16) families (Aizoaceæ, Amaryllidaceæ, Asclepiadaceæ, Cactaceæ, Cappariaceæ, Convolvulaceæ, Meliaceæ, Moraceæ, Myrtaceæ, Nyctaginaceæ, Papaveraceæ, Pedaliaceæ, Phytolaccaceæ, Portulacaceæ, Primulaceæ, and Zygophyllaceæ) are represented by only a single genus and a single species. Three (3) families (Chenopodiaceæ, Oxalidaceæ, and Plantaginaceæ) have but a single genus, but with more than one species, making a total of nineteen (19) families having only 1 genus.

Eight (8) families (Boraginaceæ, Cyperaceæ, Euphorbiaceæ, Onagraceæ, Polygonaceæ, Rosaceæ, Salicaceæ, and Scrophulariaceæ) have only 2 genera; two (Labiatae and Verbena-

ceæ) have 3. Three (3) (Caryophyllaceæ, Malvaceæ, and Solanaceæ) have 4 genera.

Only 5 families are really well represented, Amarantaceæ with 5 genera and 7 species, Leguminosæ with 6 genera and 8 species, Cruciferae with 8 genera and 9 species, Compositæ with 18 genera and 20 species, and Gramineæ with 20 genera and 27 species.

For the purposes of this analysis, two or three distinct varieties (e.g., *Lolium temulentum arvense*) have been treated as species.

This list is not as formidable as it looks; not all of the species occur in quantity, and not many of them are to be classed as noxious weeds.

#### RELATIVE ABUNDANCE OF SPECIES.

If we classify the 141 species and varieties into four arbitrary groups, (1) Abundant species, (2) Common species, (3) Adventive species, i.e., species of only local occurrence, at present, but which show signs of spreading, and (4) Colonists, or species which are rarely met with in a spontaneous condition, and which do not yet show signs of spreading, we obtain the following proportions:—

Colonists	...	...	...	...	...	...	54
Adventives	...	...	...	...	...	...	40
<hr/>							
Species only occasionally met with, as yet	...	...	...	...	...	...	94
Common species	...	...	...	...	...	...	29
Abundant species	...	...	...	...	...	...	18
<hr/>							
Total	...	...	...	...	...	...	141

Thus 94 species are met with only occasionally; they are either of very recent introduction, or are not inclined to spread.

Only 47 species, one-third of the total number, are at all common as yet.

Only 18 species, about one-eighth of the total number, are abundant.

These proportions are sure to change in the course of a few years. They are more or less arbitrary, for it is impossible to draw definite lines between the four groups. The classification is sufficiently accurate, however, to convey a fair impression of the relative abundance of the species.

Colonists (Local Species; not yet Showing Signs of Spreading).

*Acacia decurrens*, Willd.

*Agave americana*, L.

*Anagallis cærulea*, Lam.

*Andropogon sorghum* Neesii, Körn.

*Andropogon sorghum* saccharatus, Körn.

*Andropogon sorghum* Schenkii, Körn.

*Avena sativa*, L.

*Arundo donax*, L.

*Brassica campestris*, L.  
*Brassica nigra*, Koch.  
*Cæsalpinia sepiaria*, Roxb.  
*Capsella bursa-pastoris*, Medic.  
*Celosia cristata*, L.  
*Chrysanthemum segetum*, L.  
*Cotula australis*, Hook. f.  
*Cryptostemma calendulaceum*, R. Br.  
*Cyathula globulifera* (Bojer) Moq.  
*Erythrina caffra*, Thunb.  
*Eucalyptus globulus*, Labill.  
*Gossypium herbaceum*, L.  
*Hypochæris radicata*, L.  
*Linaria vulgaris*, Mill.  
*Lithospermum arvense*, L.  
*Lolium temulentum arvense* (With.) Syme.  
*Mariscus sieberianus*, Nees.  
*Medicago denticulata*, Willd.  
*Medicago sativa*, L.  
*Mentha aquatica*, L.  
*Mirabilis jalapa*, L.  
*Nicotiana glauca*, R. Graham.  
*Oenothera biennis grandiflora*, Lindl.  
*Osteospermum muricatum asperum*, Harv.  
*Pennisetum spicatum* (Willd.) Rœm. & Schult.  
*Phalaris canariensis*, L.  
*Phalaris minor*, Retz.  
*Phleum pratense*, L.  
*Polygonum amphibium*, L.  
*Polygonum convolvulus*, L.  
*Populus alba canescens*, Loud.  
*Prunus persica*, Stokes.  
*Raphanus raphanistrum*, L.  
*Ricinus communis lividus*, Jacq.  
*Rubus rosæfolius*, Smith.  
*Salix babylonica*, L.  
*Solanum pseudo-capsicum*, L.  
*Solanum incanum*, L.  
*Spergula arvensis*, L.  
*Stellaria media*, Cyrill.  
*Tragopogon porrifolius*, L.  
*Trifolium hybridum*, L.  
*Trifolium pratense perenne*, Agric.  
*Veronica anagallis-aquatica*, L.  
*Veronica Tournefortii*, C.C. Gmel.  
*Xanthium strumarium*, L.

Adventive (*i.e.*, Occasional, but Spreading).

*Alternanthera* sp.  
*Andropogon halepensis effusus*, Stapf.



*Anthemis cotula*, L.  
*Argemone mexicana ochroleuca*, Lindl.  
*Barbarea præcox*, R. Br. (?)  
*Bromus Willdenowii*, Kunth.  
*Chenopodium botrys*, L.  
*Chenopodium polyspermum*, L.  
*Coronopus didymus* (L.) Smith.  
*Cosmos bipinnatus*, Cav.  
*Dactyloctenium ægyptium* (L.) Willd.  
*Eragrostis minor megastachya* (Link) Davy.  
*Gynandropsis pentaphylla* (L.) DC.  
*Ipomœa purpurea*, Roth.  
*Leucas martinicensis* (Swartz) Ait.  
*Limeum linifolium*, Fenzl.  
*Lolium temulentum*, L.  
*Malva parviflora*, L.  
*Melia azedarach*, L.  
*Nasturtium officinale*, R. Br.  
*Opuntia ficus-indica*, L.  
*Paspalum dilatatum*, L.  
*Plantago lanceolata*, L.  
*Plantago major*, L.  
*Poa annua*, L.  
*Polygonum aviculare erectum* (L.) Roth.  
*Rumex acetosella*, L.  
*Rumex crispus trigranulata*, Syme.  
*Sesamum indicum*, L.  
*Silene gallica*, L.  
*Sisymbrium capense*, Thunb.  
*Solanum nigrum*, L.  
*Sonchus oleraceus*, L.  
*Tagetes erecta*, L.  
*Taraxacum officinale*, Weber.  
*Vaccaria vulgaris*, Host.  
*Verbena officinalis*, L.  
*Vicia sativa*, L.  
*Xylopleurum roseum* (Ait.) Raim.  
*Xylopleurum tetrapterum* (Cav.) Raim.

## Common.

*Amarantus spinosus*, L.  
*Amarantus Thunbergii*, Moq.  
*Cannabis indica*, Lam.  
*Chenopodium album*, L.  
*Chenopodium ambrosioides*, L.  
*Chenopodium murale*, L.  
*Conyza podocephala*, DC.  
*Cynoglossum micranthum*, Desf.  
*Cyperus esculentus*, L.  
*Euphorbia sanguinea*, Hochst. & Steud.



*Gnaphalium luteo-album*, L.  
*Hibiscus trionum hispidus*, DC.  
*Lantana salvifolia*, Jacq.  
*Lippia asperifolia*, Rich.  
*Nidorella auriculata*, DC.  
*Oxalis corniculata*, L.  
*Oxalis* sp.  
*Physalis minima*, L.  
*Polygonum lapathifolium maculatum* (Krock) Hook. f.  
*Portulaca oleracea*, L.  
*Ricinus communis*, L.  
*Rottboellia compressa fasciculata*, Hack.  
*Rumex ecklonianus*, Meisn.  
*Salvia obtusata*, Thunb.  
*Salvia* sp.  
*Setaria verticillata* (L.) Beauv.  
*Solanum sodomium*, L. var.  
*Tragus racemosus*, Scop.  
*Tribulus terrestris hispidissimus* (Presl) Sond.

Abundant (the Most Common Species).

*Amarantus paniculatus*, L.  
*Bidens pilosa*, L.  
*Bidens pilosa leucantha* (Willd.) Harv.  
*Cynodon dactylon* (L.) Pers.  
*Chloris virgata*, Swartz.  
*Datura stramonium*, L.  
*Datura tatula*, L.  
*Eleusine indica* (L.) Gærtn.  
*Erigeron canadensis*, L.  
*Gomphocarpus fruticosus* (L.) R.Br.  
*Gomphrena globosa*, L.  
*Lepidium capense*, Thunb.  
*Panicum helopus glabrescens*, K. Schum.  
*Panicum isachne*, Roth.  
*Sida rhombifolia*, L.  
*Tricholæna rosea*, Nees.  
*Xanthium spinosum*, L.  
*Zinnia pauciflora*, L.

#### ECONOMIC ASPECT.

It is commonly supposed that all weeds are noxious or troublesome; but this is by no means the case. They may be useful, even though they answer our definition of a weed, in that they grow where they are not wanted, be it in the mealie-patch, the flower-bed, the lawn, the footpath or the gutter. A weed, as such, is not an entity; a plant ceases to be a weed when it is not growing out of place, or where it is not wanted; Bermuda-grass is a most injurious weed in an orchard, but in a pasture it is one of our most useful forage plants. If this were

not the case there would be many more weeds, for, given suitable conditions of climate and soil, and immunity from such restrictive influences as fungus diseases and insect pests, almost any plant may become a weed.

Weeds may, therefore, be classified as (1) Noxious, (2) Troublesome, (3) Innocuous, (4) Useful.

(1.) Noxious Weeds.—*Abundant species*: *Bidens pilosa*, L., *Bidens pilosa leucantha* (Willd.) Harv., *Cynodon dactylon* (L.) Pers., *Datura stramonium*, L., *Datura tatula*, L., *Erigeron canadensis*, L., *Xanthium spinosum*, L.; *Common species*: *Amarantus spinosus*, L., *Cannabis indica*, Lam., *Cyperus esculentus*, L., *Setaria verticillata* (L.) Beauv., *Oxalis* sp., *Tragus racemosus*, Scop., *Tribulus terrestris hispidissimus* (Presl) Sond.; *Adventive species*: These, though not yet common, are likely to prove noxious; *Alternanthera* sp., *Andropogon halepensis effusus*, Stapf, *Argemone mexicana ochroleuca*, Lindl., *Lolium temulentum*, L., *Opuntia ficus-indica*, Mill., *Rumex acetosella*, L., *Silene gallica*, L., *Solanum nigrum*, L.; *Colonists*: *Cryptostemma calendulaceum*, R.Br., *Hypochæris radicata*, L., *Lolium temulentum arvense* (With.) Syme, *Xanthium strumarium*, L., *Medicago denticulata*, Willd., *Nicotiana glauca*, R.Grah., *Polygonum convolvulus*, L. The aforementioned 29 species may be considered noxious weeds.

(2.) Troublesome Weeds.—All noxious weeds are, of course, troublesome, but not all troublesome weeds are noxious. The following belong to the latter class. *Abundant species*: *Amarantus paniculatus*, L., *Eleusine indica* (L.) Gærtn., *Gomphocarpus fruticosus* (L.) R.Br., *Lepidium capense*, Thunb., *Panicum helopus glabrescens*, K. Schum., *Sida rhombifolia*, L., *Panicum isachne*, Roth; *Common species*: *Amarantus spinosus*, L., *Chenopodium album*, L., *Chenopodium ambrosioides*, L., *Chenopodium murale*, L., *Gnaphalium luteo-album*, L., *Hibiscus trionum hispidus*, DC., *Lantana salvifolia*, Jacq., *Oxalis corniculata*, L., *Physalis minima*, L., *Portulaca oleracea*, L.; *Adventive species*: *Eragrostis minor megastachya* (Link) Davy, *Limeum linifolium*, Fenzl., *Malva parviflora*, L., *Poa annua*, L., *Plantago lanceolata*, L., *Polygonum aviculare erectum*, Roth, *Sonchus oleraceus*, L.; *Vaccaria vulgaris*, Host; *Colonists*: *Brassica campestris*, L., *Brassica nigra*, Koch., *Capsella bursa-pastoris*, Medic., *Chrysanthemum segetum*, L., *Lithospermum arvense*, L., *Phalaris canariensis*, L., *Phalaris minor*, Retz., *Raphanus raphanistrum*, L., *Spergula arvensis*, L., *Stellaria media*, Cyrill., *Veronica Tournefortii*, C.C. Gmel., *Cyathula globulifera* (Bojer) Moq.—37 and 29 = 66 species which are, or may become, noxious or troublesome.

(3.) Innocuous Weeds.—These naturally include all Transvaal weeds which are not included in the two lists immediately preceding. It is, therefore, unnecessary to repeat them here.

## (4.) Useful weeds and spontaneous aliens:—

## Colonists.

- Acacia decurrens*, Willd., tan-bark, fuel, shade.  
*Andropogon sorghum* Neesii, Körn., grain, forage.  
*Andropogon sorghum* Schenkii, Körn., grain, forage.  
*Andropogon sorghum saccharatus* (L.) Körn., sugar, forage.  
*Arundo donax*, L., ornamental planting, reeds.  
*Avena sativa*, L., grain, forage.  
*Cæsalpinia sepiaria*, Roxb., hedges.  
*Celosia cristata*, L., ornamental garden plant.  
*Eucalyptus globulus*, Labill., timber, essential oil, bee food.  
*Gossypium herbaceum*, L., cotton.  
*Medicago denticulata*, Willd., forage.  
*Medicago sativa*, L., forage, bee food.  
*Pennisetum spicatum* (Willd.) Rœm. & Schult., grain, forage.  
*Phalaris canariensis*, L., bird-seed, forage.  
*Phleum pratense*, L., forage.  
*Populus alba canescens*, Loud., poles.  
*Ricinus communis*, L., oil.  
*Ricinus communis lividus*, Jacq., ornamental planting.  
*Rubus rosæfolius*, Smith., edible fruit, ornament.  
*Salix babylonica*, L., shade and ornamental planting.  
*Solanum pseudo-capsicum*, L., ornamental plant.  
*Tragopogon porrifolius*, L., garden vegetable.  
*Trifolium hybridum*, L., forage.  
*Trifolium pratense perenne*, Agric., forage.

## Adventive species.

- Andropogon halepensis effusus*, Stapf., forage.  
*Bromus Willdenowii*, Kunth., forage.  
*Cannabis indica*, Lam., fibre, bird-seed, bhang, and hasheesh.  
*Cosmos bipinnatus*, Cav., ornamental garden plant.  
*Cyperus esculentus*, L., tubers edible.  
*Dactyloctenium ægyptium* (L.) Willd., lawns, forage.  
*Ipomæa purpurea*, Roth., ornamental garden plant.  
*Melia azedarach*, L., shade tree.  
*Nasturtium officinale*, R.Br., salad.  
*Opuntia ficus-indica*, Mill., edible fruit, hedges.  
*Paspalum dilatatum*, L., forage.  
*Sesamum indicum*, L., oil.  
*Xylopleurum roseum* (Ait.) Raim., } ornamental gar-  
*Xylopleurum tetrapterum* (Cav.) Raim., } den plants.

## Common species.

- Hibiscus trionum hispidus*, DC., ornamental garden plant.  
*Portulaca oleracea*, L., salad and pot-herb.  
*Rottboellia compressa fasciculata*, Hack., forage.

## Abundant species.

*Chloris virgata*, Swartz., forage.  
*Amarantus paniculatus*, L., forage.  
*Cynodon dactylon* (L.) Pers., forage.  
*Datura stramonium*, L., narcotic poison, used medicinally.  
*Datura tatula*, L., do. do.  
*Eleusine indica* (L.) Gærtn., forage.  
*Gomphocarpus fruticosus* (L.) R.Br., fibre.

## GEOGRAPHICAL DISTRIBUTION.

One of the most interesting branches of botany is the study of the distribution of plants over the face of the globe; it is known as Geographical Botany. Its study involves a knowledge, not only of geography and climatology, but also of geology, palæo-botany, evolution, plant-physiology, ethnology, history, agriculture, and even commerce.

While primarily concerned with the investigation of the aboriginal homes of plants, a thorough student of geographical botany must necessarily investigate the origin and distribution of cultivated plants. How difficult this question is, and how much recondite learning it requires, are shown in the classic pages of that interesting work, "L'Origine des Plantes Cultivees," of the erudite botanist, Alphonse De Candolle, of Geneva.\*

But geographical botany should by no means be concerned only with the past history of plants, their origin in space and time. The facies of the world's flora is rapidly changing, and tends to become more uniform, within certain limits, under the influence of agriculture and commerce. These changes should be investigated and recorded, both for scientific and for economic purposes. The same herbaceous crops and cultivated timber trees are being carried over the world to countries enjoying similar climatic conditions. Many of the same weeds of roadside, hedgerow, and neglected farm or garden are spreading to almost every continent, limited only by restriction of climate and the bounds of commercial intercourse.

## Factors Governing Plant Migration.

The distribution of plants was for long mainly carried out by the agency of wind, currents; migratory birds, mammals, and reptiles. Latterly it has been expedited by the development of commerce and agriculture. Not only are domesticated plants carried from country to country and continent to continent, but with them are carried the seeds of other plants which have grown in their vicinity. Seeds are also carried from port to port in ship's ballast, and from place to place by domestic animals. Weeds we call some of them; colonists, immigrants, casuals, or escapes, we call others, according to their noxious

\* See De Candolle. A. ; Origin of Cultivated Plants, translated from the French. London : Kegan Paul, Trench and Co. 1884.

character, relative abundance, adaptability to naturalisation, etc.

The extent to which alien plants will spread in a country, and from one country to another, is truly remarkable. The common Pig-weed or Misbreede, *Amarantus paniculatus*, a native of Tropical America, though of quite recent introduction, is now found in every town and village of the Transvaal, and around almost every farmstead. Within about fifty years, *Bromus hordeaceus*, a native of the Mediterranean region, has spread over almost every stock-range from end to end of California. The common Wart-cress, *Coronopus didymus*, so abundant in England, on the Continent, in the United States, Australia, and elsewhere, and which has now found its way to the Transvaal, is a native of temperate South America.

The large number of alien species which now enter into the composition of the flora of almost every civilised country, is probably little thought of. It is said that even the common daisy and dandelion of England are probably aliens. In the 9th Edition of the London Catalogue of British Plants (1895), Mr. Hanbury enumerates 194 aliens out of a total of 1,958 species of flowering plants and ferns in the British Islands, an average of 10 per cent. This is a large percentage, yet it is probably incomplete, as the catalogue does not profess to be an authoritative document, as regards the nativeness of species, and species which are doubtfully native, such as the daisy and dandelion, are not there treated as aliens.

#### Origin of Our Aliens.

In order to discuss this question intelligently we must deduct from our 141 species, 15 species which are now so cosmopolitan that their original home is not known with certainty, and 2 species of which the exact identification has not yet been completed. This leaves 124 species to be accounted for.

These are distributed as follows:—

The Mediterranean Region (N. Africa, W.				
Asia, and S. Europe) ...	...	...	41	species
America, tropical and warm-temperate ...	...	...	24	„
Africa, tropical ...	...	...	23	„
Asia, tropical ...	...	...	19	„
Asia, central ...	...	...	19	„
Africa, South ...	...	...	15	„
Europe, North ...	...	...	13	„
Australia ...	...	...	3	„
America, temperate North ...	...	...	2	„
America, temperate South ...	...	...	2	„
				161

The additional numbers are due to duplication of species, which are native to more than one region.

If we exclude from our list those species which have been introduced only as ornamental garden plants or farm crops, and which have escaped from cultivation, we get the following figures:—

	Total.	Escapes.	True Immigrants.
Mediterranean region ... ..	41	8	33
America, tropical and warm-temperate ... ..	24	11	13
Africa, tropical ... ..	23	7	16
Asia, tropical ... ..	19	6	13
Asia, central ... ..	19	5	14
Africa, South ... ..	15	1	14
Europe, North ... ..	13	3	10
Australia ... ..	3	2	1
America, temperate N. ... ..	2	1	1
America, temperate S. ... ..	2	1	1
Uncertain origin ... ..	17	1	16

#### Routes of Travel.

These figures are interesting as showing the original source of supply of our immigrant plant population. It must be borne in mind, however, that the common migratory plants, and particularly weedy species, are now so widely scattered over the globe that they do not always come to us direct. Thus the common Wart-cress, *Coronopus didymus*, already referred to as a native of South America, has probably reached us via Europe, where it is now extremely common. The so-called "Australian" Prairie-grass is the Rescue-grass of the United States; it is a native of South America, whence it migrated to Texas and California, thence to Australia, and, probably from thence, to the Transvaal.

Of the 33 Mediterranean Region species (not counting "escapes"), at least 25 occur also in northern Europe, some of them indigenous there, others as aliens, and they may have reached us from that source, leaving only 8 strictly S. European species, which are not likely to have reached us from N. Europe. These are:—

*Andropogon halepensis effusus*, Stapf.  
*Eragrostis minor megastachya* (Link) Davy.  
*Gomphocarpus fruticosus* (L.) R.Br.  
*Malva parviflora*, L.  
*Panicum isachne*, Roth.  
*Phalaris minor*, Retz.  
*Portulaca oleracea*, L.  
*Vaccaria vulgaris*, Host.

All of these, with the exception of *Gomphocarpus fruticosus* and *Panicum isachne*, are common weeds in California. Of the two last-named the former is now a common weed in

Australia; the latter is common in India; it is, therefore, possible that none of them came to us direct from the Mediterranean.

The South European species may have been early importations via the Cape; *Malva parviflora* and *Portulaca oleracea* were common there in 1860, when the first volume of the *Flora Capensis* was prepared. This may have been the case also with *Gomphocarpus fruticosus*.

*Eragrostis minor megastachya*, *Phalaris minor*, *Phalaris canariensis*, *Anagallis cærulea* and *Vaccaria vulgaris* are recent introductions, the *Phalaris* from California with seeds of forage plants from the Agricultural Experiment Station there.

The one species from temperate N. America, and the one from temperate S. America, may have reached us by way of Europe, as both are now common there.

*Cotula australis* may have come direct from Australia or New Zealand, or via San Francisco, where it is now common.

The North European species, and those of S. Europe which are also found in the north, as noted above, are the most easily accounted for, because of the constant stream of traffic and commerce between South Africa, England, and the Continent of Europe, which has been going on for years.

#### *South African Species.*

The following are considered to be indigenous to parts of South Africa, but appear to be immigrants in the Transvaal:—

- Amarantus Thunbergii*, Moq.
- Conyza podocephala*, DC.
- Cryptostemma calendulaceum*, R.Br.
- Cyathula globulifera* (Bojer) Moq.
- Erythrina caffra*, Thunb.
- Lantana salvifolia*, Jacq.
- Lepidium capense*, Thunb.
- Limeum linifolium*, Fenzl.
- Nidorella auriculata*, DC. var.
- Osteospermum muricatum asperum*, Harv.
- Rottboellia compressa fasciculata*, Hack.
- Rumex ecklonianus*, Meisn.
- Salvia obtusata*, Thunb.
- Sisymbrium capense*, Thunb.
- Tricholæna rosea*, Nees.
- Setaria verticillata* (L.) Beauv.

Of this list, the *Cryptostemma* is not certainly known to occur in the Transvaal; the *Cyathula* may be indigenous; the *Erythrina* is a garden escape. The *Cyathula*, *Lantana*, *Limeum*, *Rottboellia*, *Setaria*, and *Tricholæna* are tropical African species, and their occurrence in South Africa may be either as outliers of the flora of tropical Africa, or merely as immigrants.

*Species from Tropical Asia.*

The following species appear to be common alike to tropical Asia and tropical Africa, and probably reached us from the north :—

- Andropogon sorghum, Brot.
- Andropogon sorghum saccharatus (L.) Körn.
- Eleusine indica (L.) Gærtn.
- Gossypium herbaceum, L.
- Lantana salvifolia, Jacq.
- Panicum helopus glabrescens, K. Schum.
- Panicum isachne, Roth.
- Pennisetum spicatum (Willd.) Rœm. & Schult.
- Ricinus communis, L.
- Rottboellia compressa fasciculata, Hack.
- Sesamum indicum, L.
- Solanum incanum, L.
- Tricholæna rosea, Nees.

Most of the 13 species from tropical and warm-temperate America are now almost cosmopolitan, and are not likely to have come to us directly.

Much interesting work remains to be done in tracing the origin and routes of travel of these aliens; it cannot be completed until we have access to more extensive literature on the Floras of the world. The problem is much complicated in the case of South Africa, from the fact that so much stock, forage and agricultural seed was gathered together during the late war by the Military and Repatriation Departments, from all parts of the world and has been scattered broadcast over the country. That many aliens owe their introduction to these sources is evident from the fact that they are at present found only on the sites of Military and Repatriation camps.

The notes here given are mere outlines of this part of the subject; lack of adequate literature has made it impossible to fill them out.

The methods by which alien plants are conveyed from place to place and the reasons why some species make good immigrants and quickly become naturalised, while others—apparently equally hardy—remain as mere “escapes” or occur only as “casuals,” is interesting and intricate, and involves questions of plant physiology and morphology as well as of climatology. The solution of these problems affords a valuable clue to successful plant-introduction. Some of these plants become physiologically modified by their residence and acclimatisation in another country, and become more hardy in consequence; thus of five plots of the European grass known as Italian rye-grass (*Lolium perenne italicum*), tested simultaneously on our Experiment Grounds at Potchefstroom, under precisely similar conditions, and sown on the same day, the



plot grown from New Zealand seed is superior to the plot grown from the best strains of English and Scotch seed.

We have already explained that not all immigrant plants become weeds. A few native plants sometimes become weeds when the so-called "balance of nature" is disturbed by man, either on account of peculiar morphological characters which aid in their distribution, or from some physiological condition which renders them better adapted than their neighbours to take advantage of more favourable conditions, or more hardy to withstand less suitable ones.

The "balance of nature" is so well preserved, however, that most native plants are kept within bounds by insect or fungus pests and other restrictive provisions of nature.

These same restrictive agencies apply with even greater force to many alien plants, particularly to those which we are most desirous of introducing. It is a fact noted in every country by agriculturists and horticulturists endeavouring to establish new cultural industries. It is often attributed to soil or climate; but we can scarcely consider soil and climate to be the sole cause in view of the fact that other species, from the same countries, become rampant weeds under the same conditions.

Then where *does* the difference lie? It is mainly a physiological one; it depends on difference of constitution. And here we become aware of a most important factor in successful plant introduction and cultivation. A highly bred race of barley, grown for brewing purposes, on the best tilled and most highly cultivated soils of Great Britain is not likely to have such a hardy constitution as one grown on the poorly cultivated soils of Algeria. Long cultivation and the development of highly specialised races of plants, appears to diminish their adaptability to spontaneous naturalisation in foreign countries. Few cultivated crops run wild, even under favourable conditions, and those that do so appear to be the ones that have been least altered under cultivation, and have been most recently brought into domestication. So much is this the case that we are apt to judge of the relative length of time a plant has been brought into cultivation, by its tendency to run wild. Many of our oldest cultivated crops have been so much altered by cultivation that they are no longer recognisable in a truly wild state.

But to return from a digression; the decrease in hardihood due to high breeding, is not the only factor in the problem why alien weeds grow more readily than domesticated plants, under changed conditions. If the careful attention bestowed on crops in intensive horticulture, or high farming, tends, when these safeguards are removed, to render those plants less able to withstand disease, drought and the encroachments of more vigorous weeds struggling for existence, the converse appears to be equally true, that the result of the survival of the fittest plants under the most uncongenial surroundings and least fav-

ourable climatic conditions, tends to make them better colonists. While morphological differences enable some plants to migrate more readily than others, and to survive in the struggle for existence when others go under, physiological differences render some plants more adaptable than others to varying conditions, and they, therefore, make better colonists. An Australian strain of the North European Perennial rye-grass (*Lolium perenne*) grown on dry land in Australia, and taken to California, proved so much more resistant to drought than the strains obtained from the Eastern United States, Ireland and England, that it was eagerly sought by graziers, and received the distinctive varietal name *Australiense*, though morphologically indistinguishable from a European form. At a recent meeting of the Linnean Society, Salmon reported as the result of a long series of rust inoculation experiments with *Bromus*, at the Cambridge University laboratories, having established the fact that physiological varieties exist, some resistant to rust, and some susceptible to inoculation, though morphologically indistinguishable.

The question of climate has also much to do with successful plant naturalisation. A plant which has thriven in a humid climate does not seem to take readily to an arid one, and *vice versa*. Plants from the shady forest do not usually thrive on an exposed plateau, and *vice versa*. A plant which has lived in a thermal clime does not, usually, tolerate frost; but in the latter case the converse is not equally true; a plant of the cool-temperate zone will often thrive better in the genial clime of the warm-temperate zone, than one which has always lived in the latter. Arctic plants do not, as a rule, thrive near the tropics, but those from a comparatively cold climate, if transplanted a few degrees nearer the equator, will often over-run and choke out plants indigenous to the latter; they appear to have developed a more rugged constitution under the more rigorous conditions of their original home, which enables them to oust their less sturdy neighbours of the warmer clime.

#### How Plants may Migrate.

How do weeds, not being endowed with the power of locomotion, travel from place to place? There are two classes of weed migration, the natural, in which the dissemination is unaided by man, and the artificial, including the many ways in which distribution is more or less furthered by human agency. The principal modes of distribution are here mentioned, with a few examples of each.

#### A.—Natural Dissemination.

##### *By Runners.*

*Cynodon dactylon*.

*Cynodon incompletus* (an indigenous species).

The garden strawberry is a familiar example.

*Rhizomes and Offsets.*

Agave americana.  
 Andropogon halepensis effusus.  
 Arundo donax.  
 Cyperus esculentus.  
 Paspalum dilatatum.

*Running Roots.*

Carduus arvensis (not a Transvaal species).

*Seed-throwing Apparatus.*

Euphorbia spp.  
 Gynandropsis pentaphylla.  
 Oxalis corniculata.  
 Ricinus communis.  
 Vicia sativa.

*Flying Seeds and Fruits.*

Conyza podocephala.  
 Cryptostemma calendulaceum.  
 Erigeron canadensis.  
 Gnaphalium luteo-album.  
 Gomphocarpus fruticosus.  
 Populus alba canescens.  
 Salix babylonica.  
 Sonchus oleraceus.  
 Taraxacum officinale.  
 Tragopogon porrifolius.

*Tumble-weeds.*

Amarantus albus (not yet found in the Transvaal).  
 Panicum capillare.

*Seeds and Pieces of Stem carried by Water.*

Andropogon halepensis effusus.  
 Nasturtium officinale.  
 Polygonum amphibium.  
 Polygonum lapathifolium maculatum.

*Berries eaten by Birds.*

Lantana salvifolia (?)  
 Physalis minima (?)  
 Rubus rosæfolius.  
 Solanum nigrum.  
 Solanum pseudo-capsicum.

*Seeds and Stems carried on the feet of Water-birds and of frogs  
and other Reptiles.*

Elodea canadensis (not found in the Transvaal)  
 Wolffia sp. (a native).

*Small Seeds may pass through Cattle and Horses.*

Kraal-weeds, such as the Pig-weeds (*Amarantus*), Stink-blaads (*Datura*), etc.

*Fruits (burrs) and Seeds carried by Animals.*

*Agrimonia eupatoria capensis* (a native species).

*Alternanthera* sp.

*Bidens pilosa* and var. *leucantha*.

*Cyathula globulifera*.

*Cynoglossum micranthum*.

*Harpagophytum procumbens* (a native species).

*Medicago denticulata*.

*Setaria verticillata*.

*Tragus racemosus*.

*Tribulus terrestris hispidissimus*.

*Xanthium spinosum*.

*Xanthium strumarium*.

*Spiny Fruits and Branches.*

*Opuntia* sp.

*B.—Weed Migration by Artificial Means.*

*Roots and Seeds carried by Farm Machinery.*

*Cynodon dactylon*.

*Cynodon incompletus*.

*Cyperus esculentus*.

*Seeds and Bulbs Carried in Nursery Stock.*

*Cyperus esculentus*.

*Cyperus rotundus* (a weed at the Cape, not yet recorded from the Transvaal, but to be expected).

*Weed Seeds carried in Packing Material.*

*Coronopus didymus*.

*Weed Seeds carried in Hay and Forage.*

*Amarantus* spp.

*Brassica campestris*.

*Brassica nigra*.

*Capsella bursa-pastoris*.

*Hypochæris radicata*.

*Raphanus raphanistrum*.

*Sisymbrium capense*.

*Weed Seeds carried in Commercial Seeds.*

*Phalaris minor*.

*Lithospermum arvense*.

*Polygonum convolvulus*.

*Hypochæris radicata*.

*Anthemis cotula*.

*Silene gallica*.

*Vaccaria vulgaris*.

*Cuscuta trifolii* (Dodder).

*Rumex acetosella*.

*Lolium temulentum*.

*Spergula arvensis*.

*Rumex crispus*.

*Weeds introduced intentionally as useful or ornamental Plants,  
and escaped.*

1. Farm escapes.

2. Forest escapes.

3. Garden escapes.

1.—*Farm Escapes.*

*Andropogon sorghum* Neesii.

A. — s. — *saccharatus*.

A. — s. — *Schenkii*.

*Avena sativa*.

*Gossypium herbaceum*.

*Medicago sativa*.

*Paspalum dilatatum*.

*Pennisetum spicatum*.

*Phleum pratense*.

*Trifolium hybridum*.

*Trifolium pratense* perenne.

*Vicia sativa*.

2.—*Forest Escapes.*

*Acacia decurrens*.

*Eucalyptus globulus*.

*Melia azedarach*.

*Populus alba* canescens.

*Salix babylonica*.

3.—*Garden Escapes.*

*Agave americana*.

*Arundo donax*.

*Cæsalpinia sepiaria*.

*Cannabis indica*.

*Celosia cristata*.

*Cosmos bipinnatus*.

*Erythrina caffra*.

*Ipomœa purpurea*.

*Linaria vulgaris*.

*Mirabilis jalapa*.

*Oenothera biennis* grandiflora.

*Opuntia ficus-indica*.

*Prunus persica*.

*Ricinus communis* lividus.

*Rubus rosæfolius*.

*Solanum pseudo-capsicum*.

*Tagetes erecta*.

*Tragopogon porrifolius*.

*Xylopleurum roseum*.

X. — *tetrapterum*.

*Zinnia pauciflora*.

*Railway Weeds.*

*Bidens pilosa leucantha*.

*Dactyloctenium ægyptium*.

*Leucas martinicensis*.

*Roadside or Trek Weeds.*

*Bidens pilosa*.

*Chloris virgata*.

*Eleusine indica*.

*Tricholæna rosea*.

*Towpath Weeds.*

As we have no canals, this mode of dissemination does not pertain to the Transvaal.

Considering the large number of plants under cultivation in gardens, all the world over, it is remarkable that so few of them have become naturalised in the countries in which they are grown.

Several species occur in England as casual garden escapes, but they rarely become naturalised so as to be classed as integral parts of the flora. There are some exceptions to this rule, as in the case of *Alyssum maritimum*, and *Cochlearia armoracia* (Horse-radish), both met with, not infrequently, as spontaneous plants in England, and the former well-established in California.

Still less frequently do they become troublesome weeds. But there are a few notable exceptions, as the Orange hawkweed, *Hieracium aurantiacum*, which has become such a pest in the North-eastern United States; *Lantana camara*, which in the Hawaiian Islands has completely over-run hundreds of acres of what was formerly valuable plantation land, and the Sensitive plant, *Mimosa pudica*, which is almost equally troublesome in Ceylon.

In the Transvaal, however, several species show signs of vigorous naturalisation:

*Zinnia pauciflora* is already thoroughly established and has degenerated into what is presumably its primitive form.

*Mirabilis jalapa*, the 4 o'clock, is abundantly naturalised on vacant erven in Potchefstroom and elsewhere.

*Cannabis indica*, the Dagga, is met with as an escape in almost every town and village.

My thanks are due to Dr. Bolus for kindly identifying for me some six species, and to Mr. J. Medley Wood, A.L.S., Director of the Durban Botanic Gardens, for having most courteously placed the Government Herbarium and its library and microscopes, unreservedly at my disposal, during a recent visit to Durban.

## 20.—NOTES ON THE VEGETATION OF SOUTHERN RHODESIA.

By R. MARLOTH, PH.D., M.A.

(Plate XIV.)

The following notes are the result of some observations made, during a visit of a few days' duration, in the neighbourhood of Bulawayo and in the Matopos. Unfortunately it was just the least favourable time of the year for botanising purposes, viz., the end of October, for then the rainy season has hardly commenced, and the greater part of the vegetation, from the bulbs upwards to the large trees, is still in a dormant state.

No comprehensive collection of plants, which could be compared to those of Drège or Ecklon and Zeyher at the Cape, has been made in this region as yet, but several travellers have from time to time sent home plants collected as occasion arose, *e.g.*, T. Baines, E. Holub, the Rev. W. Elliott, and Frank Oates. Recently a great increase in our knowledge of that vegetation has been effected by the collections of Dr. Rand, and it is probable that another collector, viz., Mr. Fred Eyles, who has the advantage of residing in the country, will continue to obtain further material.

The traveller from the Cape Colony who proceeds to Bulawayo by rail notices a change in the vegetation soon after crossing the Orange River. Instead of the stunted bushes scattered about on an otherwise bare ground, as in the Karroo, he sees patches of grass, which gradually increase in size, and finally, to the North of Kimberley, begin to form an uninterrupted grassveld (steppe). Scattered over this steppe are various shrubs and trees, the latter consisting mostly of Acacias, of which two species occur on the open flat ground, viz., *A. giraffae* and *A. spirocarpoides*, and one along watercourses or in depressions only, viz., *A. horrida*. Gradually, as one proceeds further north, the trees draw closer together, and soon after passing Mafeking one finds oneself in real bush country—that means to say, grassveld thickly studded with trees and shrubs.

Nearly fifty miles north of Mafeking the appearance of the landscape changes considerably, for at Lobatsi a range of hills has to be crossed, which bears a different vegetation. Most conspicuous is an arborescent species of Aloe, with a stem nearly a foot in diameter, and with a crown of very prickly leaves, the prickles being far more numerous and more thickly set than on the well-known *Aloe ferox* in the southern and south-eastern parts of the Cape Colony.

Soon after passing the Lobatsi range the railway crosses the outskirts of the Kalahari. That makes, however, little difference in the general appearance of the vegetation. It is a grass-steppe with numerous bushes and trees, the latter being not quite as large as further north. The main reason for con-

sidering this part of Bechuanaland as belonging to the Kalahari is the absence of open water. The rainfall is quite sufficient for supporting an ample vegetation, but owing to the porous nature of the soil and the absence of mountains, the water sinks into the ground and forms no springs. In the soil, however, any quantity of water exists, and wherever wells have been made or boreholes sunk they have always yielded sufficient water.

#### THE CLIMATE OF SOUTHERN RHODESIA.

As Bulawayo is situated only 20 degrees to the south of the Equator, it is obvious that its seasons must be of a more or less tropical nature. The following tables of temperature and rainfall will demonstrate this to a certain extent.

1. *Monthly minima and maxima of temperature at Bulawayo.*—Means of 4 years.

		Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept	Oct.	Nov.	Dec.
Minimum	.. ..	60.4	59.1	58.5	54.9	47.4	43.1	42.1	46.4	52.8	57.5	60.6	60.8
Maximum	.. ..	81.5	78.7	79.5	77.1	72.3	67.2	69.6	74.8	81.1	85.0	83.1	81.9

#### 2. *Rainfall.*—

		Jan.	Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept	Oct.	Nov.	Dec.	Total.
1902	Bulawayo ..	6.43	1.86	2.37	1.80	0.00	0.00	0.00	0.00	0.00	2.22	5.62	0.27	20.57
1901	Matopo Dam ..	2.48	2.43	2.30	2.62	00.0	0.02	0.00	0.00	0.00	4.00	3.45	8.84	26.14

Inches.

#### 3. *Relative Humidity at Bulawayo.*—Monthly means.

		Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1901	.. ..	58	74	74	66	52	61	48	47	44	56	62	82
1902	.. ..	73	65	65	52	51	51	47	43	36	43	61	45

It will be seen from the first table that the mean maximum of the year occurs in October, and the mean minimum in July, and that consequently these two extremes are separated by a period of two months only.

The rainfall returns show that there is no rain in winter and very little only in spring. Consequently, owing to the high temperature prevailing at the latter season, the relative humidity of the air must be very low just during the hottest part of the year. This is fully borne out by the table given above, for in 1902 it was only 36 in September, 43 in October, and 61 in November, while even December showed only 45. If one considers that these figures are the means of each month, it is obvious that the vegetation of this region must have a very trying time just at a period when, owing to the

*Note.*—The monthly means of temperature are not given as they afford little information with regard to the conditions under which the plants live.



rise of the temperature, the life of the plants has the tendency to restart its activity.

The extreme dryness of the air on some days is well illustrated by the readings which were obtained at the Meteorological Station at Bulawayo during the days of my visit to the district :—

	Dry bulb.	Wet bulb.	Rel. hum.
October 31, 1903, at 9 a.m.	83.5 deg.	60.5 deg.	23 p.c.
November 1, 1903, at 9 a.m.	84.5 deg.	60.0 deg.	24.5 p.c.
November 2	81.2 deg.	61.2 deg.	20.0 p.c.
November 3	82.0 deg.	61.0 deg.	21.0 p.c.

These figures exceed anything observed in any other part of South Africa, even in the Karroo.

This extreme dryness of the air in spring, even as late as November, explains the lateness of the period at which most of the trees regain their foliage and the herbs come into flower.

#### THE VEGETATION.

There are practically two formations only represented in the neighbourhood of Bulawayo, viz., the steppe and the flora of the rocky hills.

The Steppe: Of the various varieties of steppe occurring in Central Africa we have here almost exclusively the wooded steppe, which changes its character here and there according to the nature of the soil. This difference of soil is principally due to the occurrence of three different geological formations, viz., schists, granite, and sandstone. Bulawayo itself is situated on a belt of schist which is traversed by many quartz veins. To the south and east granite prevails, the whole of the Matopo district consisting of this rock, and to the north of Bulawayo we find sandstone, which forms the well-known landmark called Tabasinduna. As the schists produce a stiff clay soil, while the granite forms a gravelly and the sandstone a light porous soil, it is obvious that these edaphic factors must affect the distribution and occurrence of many of the plants. This influence, however, has not been investigated as yet, for a hurried visit of a few days' duration is quite insufficient for such a purpose.

Generally speaking, the ground is covered everywhere by grass, which grows to a height of three or four feet. In the beginning of summer—that means to say generally from the middle of November—the plains are green with verdure, and in the grass many herbaceous plants spring up, which, being in possession of underground rhizomes, had been able to live through the dry season and to resist the fires lighted by the natives at the beginning of the rainy season for the destruction of the old grass. Only those shrubs and trees which are able to survive the fire, either by possessing a bark which resists it or underground root-stocks which produce new shoots every year, have been left in the steppe.

Specially numerous among them are Leguminosae and Combretaceae. Of the former we have many Mimosaceae, as well as Caesalpiniaceae and Papilionaceae. Of the first of these three groups we find many kinds of Acacias. Some of them are species of a wide distribution, as, e.g., *Acacia horrida*, which is found even in the neighbourhood of Capetown, and *A. giraffae*, which occurs almost everywhere north of the Orange River. Others are of a more limited distribution. Near the ruins at the Khami were several large trees, of a species which I had not seen further south, with a trunk at least twenty feet high and a head of about sixty feet in diameter. It is very similar to, if not identical with, *A. Abyssinica*.

Among the Caesalpiniaceae are quite a number of beautiful trees, the most common one being the Mopane (*Copaifera mopane*). It is mostly scattered among the other trees, but in some parts it forms real forests. These trees have a most peculiar appearance in spring when the new foliage appears, for the young leaves are brown or reddish, even when of full size, and consequently a Mopane at the beginning of summer looks like a European oak or beech in autumn. Only later in summer, when the texture of the leaves has become more resistant, they assume their ordinary green colour. As the leaf, which has the shape of the footprint of a goat, measures several inches in length and width, it is not surprising that every traveller who crossed these regions, from Livingstone to the present day, should have admired these forests.

There are quite a number of species of Bauhinia, some only a few feet high or even trailing on the ground, as *B. reticulata*, others large shrubs or trees. Cassia and Albizzia have also a considerable number of representatives. Among the Papilionaceae are several trees with showy flowers—e.g., *Peltophorum Africanum*, with yellow flowers, and the widely-spread *Burkea Africana*.

A few only of the many Combretaceae can be mentioned here, e.g., *Combretum holosericeum*, *Pterocarpus sericeus*, and others, most of them, as the names indicate, with silk-haired leaves, a sign of the xerophilous climate.

Among the shrubs of other orders is the most remarkable one, an undescribed species of Protea. Although this order is one of the largest in the flora of South Africa, it is almost confined to the south-western districts of the Cape. A few outliers follow the mountain ranges of the south-eastern and eastern coasts, Natal possessing three species of Protea, against 75 in the Cape Colony. It is also known that a few species occur on the East African mountains, e.g., *P. kilimandscharica*, and that one is found in Abyssinia, viz., *P. abyssinica*. Quite recently six new species were discovered by Baum in the hinterland of Mossamedes, near the headquarters of some tributaries of the Zambesi. But in the enormous intervening region no member of this genus was known to exist, and only one repre-

sentative of the whole order had been found quite recently, viz., *Faurea saligna*. This tree yields the famous Terblans wood, and occurs at Knysna as well as in the Matopos and on the upper Zambesi. The species of *Protea* found here resembles shrubby forms of *P. grandiflora* in its habit to such an extent, that I thought it was the same species when I caught sight of it for the first time from the train, about 15 miles south of Bulawayo. Even the colour of the foliage is the same glaucous hue, and the leaves are twisted at their base in the same way, in order to point their edges against the midday sun, as many species of *Protea* do at the Cape, particularly also *P. grandiflora*.

Another isolated type from the Cape was a species of *Gnidia*, but as the *Thymelaeaceae* are not so exclusively southwestern, its occurrence is less remarkable. Among the small shrubs were fairly common *Zyziphus mucronata*, sometimes growing to the size of a well-shaped tree, *Carissa tomentosa*, of the habit of the more southern *C. arduina* and *Grewia cana*, which seems to grow everywhere between the Garib and the Zambesi. Conspicuous in the grassy plains was the beautiful *Combretum Oatesii*, which attracted the eye not only through its bright scarlet flowers but also its capsules of the same colour. A species of *Anona*, viz., *A. senegalensis*, with shoots only a foot high, was just in flower, and was said to bear edible fruits (custard apples). Trailing on the ground were found *Boerhaavia plumbaginea*, *Pretea eriocarpa*, and *Cassia arachoides*, while a few of the herbs and shrublets which grow in the grass were just coming into flower, viz.: *Cleome pentaphylla*, and *C. monophylla*, *Gynandropsis pentaphylla*, *Sida longipes*, *Melania linearifolia*, *Linum Thunbergii*, *Monsonia ovata*, *Vahlia capensis*, *Nidorella namaquensis*, *Helichrysum setosum*, a *Wahlenbergia*, and several species of *Gomphocarpus*, *Ceratostigma plantagineum*, *Withania somnifera*, *Aptosimum lineare*, *Sesamopteris pentaphylla*, a *Justicia*, *Lantana salviaefolia*, *Serico coma angustifolia*, and *Achyranthes aspera*.

#### THE HILLS.

The Matopos are not a range of mountains, as is often thought, but they consist of a broad granite belt about thirty miles long, which by the forces of denudation and erosion has been cut up into thousands of granite hills and hillocks, varying in diameter from a hundred to that of a thousand feet or more, but hardly ever exceeding a height of 400 or 500 feet. These hills often consist of one huge mass of granite, whose flanks may be absolutely bare for hundreds of feet, but which often carry boulders of all sizes and shapes on their more gentle slopes. It is one of these hills which was named by the late Mr. Rhodes the world's view, and which now forms his last resting-place.

The flora of the rocky part of the country differs from that of the plains by being far more varied. Even the rocks and

boulders are not really bare, although they appear to be so when seen from a distance. They are covered with thickly-set lichens of various colours, which show up very brightly during rainy weather, when the tissues have become filled with moisture.

Almost all the trees, shrubs, and herbs observed in the open country occurred also on and among the granite hills of the Matopos, but besides these there were many other conspicuous types.

Between the boulders or in the cracks grow several large species of *Ficus*, among them *F. natalensis*, which occurs not only in Natal but also near Kuruman, in Damaraland, and even in the Karroo. Some other species of *Ficus* had handsome large leaves, as large as those of the cultivated species, and an *Erythrina*, viz., *E. latissima*, had not less luxuriant foliage, but formed, when not so far advanced and consequently just in flower, a far more beautiful sight, owing to its large bunches of scarlet blossoms. Not less beautiful was the Rhodesian mahogany tree, *Afzelia cuanzensis* Welw., with its shining green leaves, and racemes of red flowers, and the somewhat smaller *Dicrostachys*, with its purple blossoms. Many *Acacias*, *Cassias*, and *Entadas* grew on these rocks, one species of *Cassia*, viz., *C. abbreviata*, bearing pods that were 18 inches long. Very common was also *Elephantorrhiza Burchellii*, forming numerous light green patches on the granite.

The most striking forms of vegetation, however, were the tree *Euphorbias*, of which two species occur in the Matopos, while only one of them, viz., *E. Reinhardtii* Volk, was noticed on the hills near Bulawayo and in similar localities near the railway line as far south as Francistown. The same species occurs also at Natal, evidently having a wider range than any of its African allies. The other species, with somewhat drooping branches, has been identified as *E. angularis* Klotzsch. Associated with it was mostly a very tall *Aloe*, with a stem 15 feet high, forming a most conspicuous object here as well as between the ruins at the Khami. Of smaller succulents I might mention that I saw only one other species of *Aloe* of the stemless form, one *Kalanchoe*, one *Crassula*, and one *Stapelia*. The latter formed large groups on some of the granite slopes, but neither of these plants being in flower, their identification will have to wait until the specimens which I am cultivating produce flowers or until someone else collects them at the proper season.

Of other smaller plants I must not omit to mention *Vellozia retinervis*, for it belongs to a family mostly occurring in Brazil, but having a few representatives in tropical and subtropical Africa. The plants might be described as miniature grass trees, for the stem is only a couple of feet high, bearing a bunch of grass-like leaves at the ends of the branches, from which also the blue flowers arise.



Here also grew numerous shrublets of the very remarkable *Myrothamnus flabellifolia*. This genus has flowers of such a peculiar structure that it had to be placed into an order by itself, viz., Myrothamnaceae, which consists of two species only. The shrub is biologically very interesting, for it forms a kind of resurrection plant. In winter the shrublets, which form fairly large patches on the hills of the Matopos, look quite brown. They have not dropped their leaves at the beginning of the dry season as so many other trees and shrubs of this region do, but they have simply folded them. In that state the leaves last through the dry season, looking quite withered and dead, but when the rain has filled the air with moisture, they unfold, exhibiting again their bright green surface.

The valleys between the hills were covered with high grass, and scattered over the grassy plains were various trees and shrubs, particularly Acacias, the so-called Kaffir orange (*Strychnos*), *Parinarium mobola*, and some specially fine specimens of the *Faurea saligna*, some of them being 40 feet high, with a trunk of 20 inches in diameter. Here also the *Protea* grew more luxuriantly and helped to form a most interesting association of plants.

Among numerous Leguminosae and Combretaceae, over which the *Cissus* (*C. Marlothii Gilg.*) from the forest region as well as the leafless *Sarcostemma* climb, and on which numerous *Loranthus* display their gorgeous flowers, grow tree *Euphorbias* and arborescent *Aloes*, side by side with the *Protea* and *Faurea* from the typical Cape flora. The *Stapelia*, one of the most prominent Karroo types, hides itself in the shade of the representative of the Brazilian Velloziaceae, and in a pool at the foot of this cliff stand the blue stars of the common African water lily (*Nymphaea stellata*). In the grass near the water's edge are numerous plants of a small *Drosera* and several species of *Lobelia*, and in a sandy patch close by the gorgeous flowers of *Gloriosa superba* and a dwarf custard apple. Not far from it occurred the almost cosmopolitan *Ophioglossum vulgatum*, and in a hollow formed by some boulders and overhanging rocks the royal fern (*Osmunda regalis*), growing most luxuriantly to a height of 6 feet, while some rocks, kept moist by a constant drip from above, were covered with groups of *Streptocarpus*.

These observations, although of a very limited character, will show that this part of Rhodesia belongs to the large floral kingdom of central and sub-tropical Africa. Many genera and even some species are identical with those of Angola and Central Africa on the one side and with others from Bechuanaland, the Transvaal, Natal, and even the south-eastern Cape Colony on the other side, but there are only very few representatives of the real Cape flora and the Karroo.





*R. Marloth: Vegetation in the Matopos.*



EXPLANATION OF PLATE XIV.

Vegetation in the Matopos.

The large tree is *Faurea saligna*, to the left of it are shrubs of *Protea*, in the centre *Acacias*, on the right-hand side a Kaffir orange tree.

## 21.—BIOLOGICAL AND ETHNOLOGICAL OBSERVATIONS ON A TRIP TO THE N.E. KALAHARI— SEPTEMBER, 1903.

By S. SCHÖNLAND, Hon. M.A. (Oxon.), Ph.D., F.L.S., C.M.Z.S.

Apart from traders passing to and from Lake N'gami, the part of the Kalahari which I visited in company with Dr. J. B. Greathead in September, 1903, has been rarely visited by white people. We went by rail to Palapye Road Station, then by waggon almost due west 38 miles to Serowe, and proceeded on the road to Lake N'gami, nearly 50 miles in a north-westerly direction, as far as M'moonve pit. From there we penetrated westwards into the Kalahari for a distance of about 24 miles. Our trip was purposely undertaken in the dry season, as our object was to procure skins of some large animals, especially Eland, for the Albany Museum and the United States National Museum. We were successful in our main object, but though the season was most unfavourable for biological observations, and though our movements were regulated by the exigencies of the chase, and the time very limited, we were able to collect a few other interesting Natural History and Ethnological objects, and to make a few observations which, though small in number, suggested some problems in Natural History, Ethnology, and other subjects, with which I will deal briefly to-day. If I can manage it, I hope to follow up my last trip at no distant date, and thus perhaps be able to contribute towards the solution of these problems; but I shall be amply repaid if my paper helps to direct the attention of competent observers to the Kalahari, the least explored part of South Africa at the present time. It affords an immense field of exploration for the Anthropologist, the Botanist, the Zoologist, the Geologist, and the Meteorologist.

The average altitude of the country we traversed from Palapye Road Station is about 3,700 ft., nearly as much as the neighbourhood of the country round Kimberley. At Serowe it was actually 3,700 ft.; twenty-five miles further north the road had risen (as indicated by my aneroid) to about 4,100 ft., at M'moonve it was 3,500 ft., 14 miles further west it was 4,900 ft.; from there it fell about 400 ft. in the next 12 miles. These figures, which are only approximate, show you that the country generally is greatly undulating. In addition to these more or less gentle undulations of the general surface of the country, there are numerous hills from the neighbourhood of Serowe onwards to beyond M'moonve, some of which are characteristic table mountains rising abruptly from the plain. The soil is mostly of a sandy nature.

The chief rainfall occurs in summer, and must, as a rule, be very copious. The result is a wonderfully rich vegetation, quite unlike what one would expect in a so-called desert. I may remind you that in the North African deserts the rainfall is restricted to the winter and early spring.

so that few plants can flourish during the pitiless heat of the summer.

From Mafeking to the furthest limit of our trip we travelled through nothing but richly-wooded country. In the desert the trees were, perhaps, as a rule somewhat further apart, and not quite so high, but their character did not change. It is true some species were found only in limited areas, but no apparent reason could be assigned for these facts of distribution, to which further attention should be devoted at a season when the trees are in foliage and flower, so that they can be readily determined. I could not recognise many of the trees, as I saw them only in their winter garb, without leaf, flower, and fruit. Of those which I could locate in the natural system, several species of *Bauhinia*, to which the dry leaves of last year's growth still clung, showed in most artistic variegated colours. Besides these, there were a number of species of *Acacia*, some *Combretaceae*, some *Sterculiaceae*, a tree-*Euphorbia*, but no palms, and the Baobab was also absent. A species of *Rhigozum* and two species of *Strychnos* were very common, and the former when in flower brightened up the landscape considerably. A few *Stapelias* were noticed along the road, one of them the foul-smelling *Caralluma lutea*, which also occurs near Kimberley. An arborescent *Aloe*, reaching about 12 ft. in height, was not uncommon, especially on the tops of some low hills. There were also found three other *Aloes*, two of which (*A. Greatheadii* and *A. bamangwatensis*) have already proved to be new to science. Of these *Aloes* none formed a conspicuous feature of the vegetation. There was a fine *Kalanchoe* fairly common, but, apart from these, succulents were absent. Various kinds of *Loranthaceae* presented themselves on the trees. There were also remains of *Cucurbitaceae*, and judging from the collections made by Capt. Lugard, some of which we have in the Albany Museum, fine bulbous plants must be rather common. There was everywhere an abundant growth of grass, which belonged mainly to the genera *Andropogon* and *Aristida*, and which seemed to be identical with species which are well known from the Transvaal and elsewhere. I will not dwell further on the vegetation, for I had, as previously remarked, no opportunity of studying it thoroughly, although what we saw gave one a good impression of its general character, and confirmed the general idea that it forms with the greater part of the flora of the Transvaal a well-defined botanical region, which has been called the Kalahari region. It is a pity this name has been generally accepted, as a region should not be called by its poorest portion, and the greater part of the Kalahari is much poorer even than the part we visited. I wish we could change it into "South African Park Region," for the general resemblance of the country to an English Park is very striking, with its trees dotted about everywhere and its luxuriant growth of grass.

can races very well, would never have expected. His people, although they have adopted the veneer of European civilisation, live very much the same kind of lives as their forefathers did, if allowance is made for some altered circumstances, especially the influence of religious teaching, and the absence of tribal wars, which they owe to the protection of the British Crown. The construction of their huts, the laying out of the villages with the Khotla near the Chief's residence, the dealing out of justice to ordinary offenders, the tilling of the fields, and many other things are very much the same as in the time of Burchell, more than 70 years ago. Altogether the Bechuana tribes, as far as I know them, have proved most conservative in many of these matters, though a change, which is not always for the better, is gradually coming over them, probably due to the influence of the railway, which runs right through their territory. I was told that at Serowe (though not at Mochudi) the making of the beautiful pots for which the Bechuana tribes are famous, is gradually dying out, and is now entirely done by the Makalakas at Serowe. I have never seen the making of these pots, but I was fortunate in witnessing the burning of some, and was astonished to find that this was done in a brisk open fire on a wind-swept spot. Every day one sees at Serowe hundreds of women carrying these pots gracefully on their heads on their way to and from the water, but already there is a good sprinkling of paraffin tins amongst them, and for cooking purposes iron pots are rapidly taking their place. This is a good thing for the traders and the European manufacturer, but a sad sight for anybody who is interested in the handicrafts of primitive people. I could say a great deal more about the Bamangwatos, but very little that is new. I will only refer to one matter with which we became acquainted. The Rev. Mr. Willoughby, until recently Resident Missionary at Serowe, and who, by the way, is brimful of interesting information on these people, which only somebody who is in their confidence could obtain, and which, I hope, he will soon be induced to publish, told us that there are numerous walled enclosures in the country, enclosing the sites of former Bamangwato stadts and which to this day they keep secret from Europeans. We never saw any of these, but Dr. Greathead happened to come across two ancient Bamangwato settlements on two low hills near M'moonve, which I subsequently visited. They proved to me that without doubt the country must have been much better watered in former times, and consequently must have been more habitable than it is now. It remains, however, to be investigated whether this condition of things existed only for a certain period, or whether, as is frequently assumed, this territory, as South Africa generally, is undergoing a marked and steady process of desiccation. There are weighty reasons against the latter assumption, though it is very generally adopted. On the sites of these two settlements

we found innumerable bits of pottery of the same type as the pottery made to this day, large numbers of stone implements, especially scrapers and knives ; and I happened to find a small stone-bead which is of the same type as the digging stones of the Bushmen, with double bell-shaped perforation. Khama told me expressly that his people used to make such beads, otherwise I would have ascribed it to Bushmen. There were also numerous ostrich-shell beads, some still without perforation.

I have already incidentally mentioned that there are Makalakas at Serowe, where they reside in fairly large numbers. Their presence is due to the fact that in former years they found a safe refuge among the Bamangwatos from the attacks of the Matabele, who drove them out of their more northern homes. They are, like the Bamangwatos, Bantus, and their language is said to be closely allied to Sechuana, or as our Makalaka cook expressed it, " It is Sechuana but not like it." At M'moonve we made the acquaintance of a third tribe, who spoke quite a different language. Spoken, as it was, by men and women alike in a high-pitched voice, it sounded at a distance somewhat like the croaking of our South African frogs or sometimes like the cackling of hens. However, when spoken quietly, *eg.*, in answer to our questions, which, of course, had to be translated first into Kaffir, then into Sechuana, which these people understood, but as a rule did not speak, it was not unmelodious, though full of soft clicks. In appearance, as you will see from my photographs, many of them could be matched amongst any Bantu tribes, though there are differences which become apparent only on closer acquaintance. Their limbs are more slender than in Bantus, the forehead is wrinkled even in young children, the breasts of the women are poorly developed. The height of the men was on an average about 5 ft. 6 in., but one was 5 ft. 9 in. high. Rough measurements of their well-formed heads did not differ materially from that of a Kaffir who was with me. The average height of the women was 4 ft. 8 in. They carry themselves with an easy grace. In general behaviour they are gentle. The men are unsurpassed as spoorers, and their powers of endurance are scarcely creditable. These people were introduced to us by our Bamangwato hunters as Masaras—they themselves called themselves Magwaras. I knew, of course, that by Masara the Bechuanas designate the Kalahari Bushmen, but though the Kalahari Bushmen are generally known to be much taller than the Colonial Bushmen, I could not see the slightest racial resemblance between these people and the Colonial Bushmen of whom I have been fortunate to see a few in former years, and of whom I have seen numerous illustrations. I will say at once that it seemed to me that these people had a large admixture of Bantu blood, and that they cannot be looked upon as typical specimens of the Kalahari Bushmen, though Dr. Nobbs, who had just returned from the S.W. Kalahari when I

lumped together by the public and by that class of writers who have blessed us with such a large flood of books on South African travels, in which usually the greater part is taken up with such difficulties as waggon-travelling in the interior invariably brings forth, and with hunting adventures. We still want a competent anthropologist to give us an exhaustive treatment of what can still be known of these marvellously interesting representatives of primitive mankind which have been lumped together as Bushmen. It is a pity that Fritsch did not penetrate beyond the Bamangwato capital, and thus missed the opportunity of acquiring information about the Masaras at first hand. As far as I know, only one traveller, Mr. Andrew A. Anderson, has clearly expressed the opinion that there are several kinds of Bushmen. In his "Twenty-five Years in an Ox Waggon" (London, 1888; p. 218) he states that there are four types of Bushmen in the Kalahari—the first, very wild and only rarely met with, has no forehead and half wool and hair on their bodies. The second is the wild Bushmen who live in the mountains near the Orange River, who war on all men, but are of good form, without hair. The third is the Masara Bush family, also of good proportions and of gentle disposition, inoffensive and harmless, ready to help and do anything, they make good servants. The fourth (by which he probably means the Bakalahari, which are generally looked upon as an impoverished Bantu tribe) is much taller and well formed, great rascals who cannot be trusted with anything. They inhabit the eastern portion of the desert and down by the Langberg. The Bushmen of the Northern Kalahari are much the same as the Masara, but he adds, and he speaks from personal knowledge, *every one quite distinct from the Drakensberg Bushmen, whose form and colour differ entirely from the others, which I believe to be a distinct race.*

As I am writing these notes I am ignorant of the arrangements which have been made for the reception and entertainment of the British Association next year, but I think their visit could be utilised for bringing this and similar questions to a successful issue. If sufficient inducement were held out to them, there will be a chance of prevailing upon some of the best anthropologists of the world to tackle such problems, and I would suggest that at various centres where a longish stay is made, representatives of the various tribes be collected together for investigation. Thus in Cape Town we could have Hottentots and Bushmen from the south-western Kalahari; in Johannesburg, no doubt, numerous Bantu tribes and some remnants of the Drakensberg Bushmen could be collected together; in Kimberley, Bulawayo, or some other centre along the line to the Victoria Falls, the tribes from the eastern and north-eastern Kalahari could be represented. If, in addition to this, the various museums would combine to exhibit in one centre their osteological material, the bait would be over-

whelmingly tempting for any European or American anthropologist who could join in the visit. The expense would be inconsiderable, and no doubt the various Governments and Native Chiefs would help, and thus an opportunity could no doubt be utilised which, with the changes that constantly take place amongst the natives with advancing civilisation, will never occur again.

ever, was a ripe female got. This was one of 684 specimens brought up in the trawl from about 100 fms., 14 miles off Cape Point.

The eggs procured were clear, homogeneous, and floated on the surface of the water in which they were placed. They were of a fairly uniform size, ranging from 1.15 to 1.06 mm., the oil globule, which was yellow or red in colour, being from .29 to .27 mm. The vitelline membrane was thick (about .02 mm.), and marked in a very distinctive manner. In some cases the markings appeared to be separate dots only, but these were seen in many to be connected by fine hyaline lines, so as to form polygonal markings on the surface of the egg. The dots themselves were seen under a higher power to be small connecting pillars between the outer and inner surface of the vitelline membrane. On another occasion, while trawling 39 miles off Cape Point in 310-560 fathoms of water, one ripe female out of 145 specimens of *Macrurus parallelus* was found. The eggs proved to be of exactly the same general character as those of *M. fasciatus*, but somewhat smaller in diameter.

There is a peculiar problem in connection with the eggs of deep-sea fishes. It is well known that when brought up from great depths deep-sea animals suffer considerable damage from the great difference of pressure. With the exception of some eels, which for a few minutes retained some sign of life, all the deep-sea fishes procured by the *Pieter Faure* were quite dead when brought on deck. Where, then, are the eggs deposited? If they float to the surface will they not suffer the same fate as the fishes? To settle this point it is of importance to examine the tow-nettings for any eggs similar to those above described. During the time the *Pieter Faure* was engaged in deep water work off Cape Point none of the surface tow-nettings were found to contain any eggs at all corresponding to these, but on four occasions one or two eggs procured in the tow-net attached to the beam trawl exhibited all the characteristics described above. The polygonal markings were very distinct, as well as the connecting columns. They were procured at a distance of from 8 to 47 miles off Cape Point, in depths ranging from 91 to about 1,000 fathoms. They varied from 1.07 to 1.15 mm. in diameter, with one oil globule from .25 to .3 mm., measurements which are so similar to those of the eggs of *Macrurus fasciatus* that there is no reasonable doubt but that they belong to this fish. The manner in which they were procured seems on the whole to point to the fact that their natural place of occurrence is at or near the bottom of the sea. As against this supposition, however, we have to bear in mind that the eggs when procured from the ripe female floated, and that the bottom net was not a closing one. Neither of these considerations are conclusive, however, as the fish from which the eggs were procured had been brought up from a depth at which there must have been great pressure, and the



eggs under these new conditions of diminished pressure might float. Again, as against the second objection, we have to consider that on none of the four occasions in which the eggs were procured were any found in the surface tow-net which was in use at the same time. The question can only be satisfactorily settled by the use of a closing net.

The eggs of a very common fish, the "Panga" (*Pagrus laniarius*, C. and V.) have been procured from the female, but later stages have not been observed. They vary from .93 to 1.02 mm. in diameter, and contain a single oil globule .19 mm. in diameter.

The ripe eggs of *Stromateus microchirus*, Bonap. have been secured and fertilized. They contain several oil globules, and vary from .81 to .85 mm. in diameter. The larva is short and stumpy.

On one occasion, while trawling in False Bay, a ripe male and female of the "Horsefish" (*Agriopus spinifer*, Günth.) were found, and fertilized eggs secured.

A deep-sea fish which was procured proved to be the adult of *Catactyr Messieri*. The eggs were mature, and curiously enough were of the deep red colour characteristic of many deep-sea animals. The most noteworthy feature was the presence of embryos amongst the eggs, thus proving that the fish is viviparous.

The eggs of another fish were procured in fair abundance, and when hatched out proved to be those of a *Scombresor*, specimens of which, in various stages of development, were found in tow-nettings along with them. The eggs did not, however, have the peculiar filaments characteristic of those of *Scombresor saurus*, which is reported to occur in South African waters, but had merely a number of minute dots closely placed over the whole surface of the egg.



**SECTION C.**

**AGRICULTURE, ARCHITECTURE, ENGINEERING, FORESTRY,  
GEODESY AND SURVEYING, SANITARY SCIENCE.**



## SECTION C.

### PRESIDENT'S ADDRESS.

#### IMPROVEMENTS IN ROLLING STOCK.

BY LIEUT.-COL. SIR PERCY GIROUARD, K.C.M.G., D.S.O., ETC.

Before commencing any description of the stock in use on the Central South African Railways, it is as well to give a general statement of the conditions obtaining on these lines which govern the system of working.

These conditions are in many respects unusual, and are more nearly like those obtaining in America than those to be met with in Great Britain.

The lines are of 3 ft. 6 in. gauge, the original permanent way consisting of rails weighing 60 lbs. per yard, with some 52 lbs. section in places. They are of the "vignoles" type, laid on steel or wooden sleepers. Ballast is on an average good and plentiful.

The 80 lb. rail is now taking the place of the 60 lb. in the main lines. The grades are heavy, varying from 1-100, which will be the standard for new main lines, to 1-50, which is common on old main lines in the Transvaal; curves are sharp, and there is very little level, and passenger traffic is, therefore, of necessity slow.

The traffic is principally long-distanced, and consists largely of general goods and machinery for the mines, which can be run in large loads in high-capacity trucks.

There is a heavy coal traffic to the mines and to the Cape; most mines now have coal stages, permitting the use of hopper-bottomed trucks.

There is a certain amount of local traffic which must be accommodated in 4-wheel trucks.

Enough 4-wheeled trucks were found on the lines to meet local traffic, but they are of bad design and suffer badly from contact with the heavier bogie stock; under-frames and buffing gear have to be strengthened; weight, usually  $5\frac{1}{2}$  to 6 tons; load, 11 to 12 tons.

While the lines were still under military administration it was seen that more stock would be required, and it was decided without delay to order improved vehicles more suitable to the traffic, and orders were accordingly placed for two types—a

high-sided steel bogie of 60,000 lbs. capacity and a tare of 30,500 lbs., and a pressed steel coal Hopper-bottomed car of 60,000 lbs. capacity and a tare of 29,600 lbs. The first were built in England and the second in America. The latter trucks were very rough and cheap, but have so far given no trouble and have every appearance of lasting well.

Almost before these arrived it was seen that they would not meet demands, and orders were placed for 1,250 more bogie cars. Their capacity was at the same time raised, 1,000 being of structural sections with a capacity of 70,000 lbs. and a tare of 30,200 lbs., while the last 250 were of pressed steel, with a capacity of 70,000 lbs. and a tare of 29,200 lbs. As the number of hopper stages increased an additional number of hopper vehicles were indented for, 100 being of structural sections and 150 of pressed steel, having a capacity of 85,000 lbs. and a tare of 36,500 lbs. The percentage of paying load to tare has thus been increased from 66 per cent., in the case of Z.A.S.M. stock, to 77 per cent., in the later type.

As it is thought we can improve still further on these figures, and as it has been found that there is very little deflection even with a load of 100 tons put in with vehicles only bolted up, it is now proposed to build a wagon with a capacity of 85,000 lbs. and a tare of 32,000 lbs., so designed as to carry a load of 100,000 lbs. where the 80 lb. rail permits an increase.

In anticipation of an increase of local traffic, other designs for 4-wheel stock have been prepared, with tare of 15,500 lbs., and load 43,500 lbs.

Passenger traffic is of two kinds - long-distance through traffic and local or suburban traffic.

The stock in hand during the military regime consisted of short 4-wheel coaches of little value and some 100 bogie coaches of various patterns up to 55 feet in length, the weight of these coaches worked out roughly for accommodation to about 1,500 lbs. per passenger.

While still a military concern, a number of modern bogie coaches, 60 feet in length, with all possible conveniences, such as electric light and fans, hot and cold water baths, steam heat, full vestibules, etc., were ordered, as well as some 55 coaches for local service.

It is interesting to know that these vehicles have been much admired by English experts and are sure to increase the comfort of travelling in South Africa.

To provide for traffic along the Rand, a number of suburban coaches with side doors were ordered, with 60 ft. frames and bodies 9 ft. 1 in. wide over mouldings, and trains consisting of day, buffet, and baggage cars for the Pretoria-Johannesburg service were arranged for, and are now under weigh. The side-door coaches carry as many passengers as eight old Z.A.S.M. shorts, and weigh about 1,000 lbs. per seat.

Of miscellaneous vehicles, 50 coaches for conveyance of Kaffirs have been ordered, and the old stock of cranes has been increased and improved by the provision of one 20-ton hand crane, four 15, two 10, and four 5-ton cranes.

All stock is fitted with vacuum brake, and all new passenger vehicles with automatic couplings.

It is natural that the increase of traffic should have thrown a heavy strain on the locomotive stock, and the chief trouble has been under this head. Some 340 locomotives of some 12 different designs formed the stock with which the railways started work as a system; not one of those designs could be called satisfactory in respect of power. The tractive force of the Netherlands' and Free State engines was 19,000 lbs.

The first engines to be obtained were six Australian tank engines then available in Great Britain, and some Rhodesian and Cape 7th class locomotives were put to work of a tractive force of about 20,000 lbs.

These were followed by 15 of the much-debated "Reid" 10-wheel coupled engines, tractive force 34,000 lbs., and whatever may be said of these engines, no one can deny that they saved the situation, and rendered possible an immense improvement in the goods and coal services. Without them, I am afraid to say what would have been the result; it is interesting to note that they take the same load that was, up to their arrival, hauled by two of the original classes, and so far no later engine has exceeded them in tractive force.

There was every appearance of traffic developing rapidly, and a further 20 Reid engines were obtained, as well as 40 8th class—an excellent goods type, of a tractive force of 28,000 lbs.

When the Civil Government took over the lines, 60 more 8th class were added to the stock. In the beginning of 1903 the question of passenger engines began to be discussed; 8 tank engines and 4 passenger engines were ordered, and it is probable that these two latter classes, with the 8th class, which they duplicate in most particulars, will represent the three standard designs for 60 lb. rail.

Subsequently the question of increasing the weight of rail came under discussion, and designs for engines to take full advantage of the 80 lb. rail have been worked out, and 35 engines are under construction of a tractive force of nearly 39,000 lbs.

It is interesting to note that the latest Central South African Railways goods and passenger engines have higher tractive force than any English engine at work up to six months ago.

To the great progress of the science and economics of communication do we mainly owe the extraordinary advancement of our South African Colonies during the last few years, and to continued improvement of communications must we look for a large measure of the successes—agricultural, industrial, or mining—to be achieved in the great future undoubtedly reserved for these communities. We must look to the economics

of haulage and the aims which science, as well as human endeavour and intellect, can give us to attain those results best calculated to serve all and every national and personal interest of the future.

The battle of the gauges so keenly fought has for the present been settled for South Africa. Are we doing the best we can with what has been passed down to us; if not, how far can we go? In my review I propose to confine myself to an outline of the progress of economical haulage in the two new Colonies, in which, however, we are working hand in hand with our neighbours towards a common result. I will leave aside for the moment the question of the haulage of passengers, to treat of the more important subject of the haulage of goods. The economical haulage of goods depends mainly upon—

- 1st. The capacity of the locomotive engine.
- 2nd. The dimensions and tare of the wagons.
- 3rd. The nature of the design of the railways.
- 4th. The interest payable on capital.

The Locomotive Engine is the decisive factor in all the others. Prior to the war the power of the locomotives of these railways was equal on a 1 in 100 grade to about 500 gross short tons. During and since the war the capacity has been increased to about 730 tons, and with the engines now on order the gross load will reach 1,000 tons, resulting in the production for a 3 ft. 6 in. gauge of a machine equal in power to any standard gauge engine ordinarily employed in goods traffic on the railways of Great Britain. With this machine it would seem that our limit has been reached for our gauge, for the centre of gravity cannot go higher. We have now exceeded in this respect the safe limit of twice the gauge. Possibly the load may be increased by the use of double engines of "Fairlie" or "Kitson-Meyer" type to more than the 1,000 tons, but we have reached the limit for one driver and fireman. The engine weighs some 130 tons, and to work it efficiently demands a rail of at least 80 lbs. to the yard, with an increased number of sleepers; so much for the governing factor. All other charges are dependent upon it, and their improvement or alleviation will from time to time fix the lowest rate at which a ton can be hauled one mile. That what seems to be our limit in engine power should have been reached is perhaps not consolatory, but that it should have been attained so quickly, by doubling our power in less than five years, and reaching on a narrow gauge such a high standard, is a matter for congratulation, and deserving recognition of the merits of our locomotive engineers and management. It shows that the capacity of our lines on the basis of our old power can, without doubling any lines, be increased 100 per cent. in the future, thus leaving a large margin for gradual development to that standard, with ever-increasing economy of haulage.



Goods Stock.—When the railways of the new Colonies were taken over the bulk of the goods wagons weighed about 6 tons, and carried about 12, constructed mainly of built-up steel frames with wooden bodies. During and since the war a carrying capacity, equal in tonnage to what existed, has been added. The new stock has been entirely steel, 29,000 lbs. to carry 60,000; 31,000 to 32,000 to carry 70,000; and 35,000 to carry 85,000.

There has not been a very noticeable increase in the proportion of dead weight to carrying capacity, but manifold advantages in haulage have accrued. The load of the latest type of engine on a 1 in 100 grade will approximate 1,000 gross tons. With the old stock 55 wagons would have been necessary, some 1,200 feet in length of train and on 220 wheels, the dead weight reaching some 330 tons. With the new stock some 19 wagons would be necessary, of a length of about 650 feet and on 76 wheels, the dead weight reaching 300 tons. Leaving aside the difficulty of maintaining an efficient vacuum on the brakes of 55 wagons, consider the economy of curve and grade resistance, maintenance, and repairs, can it be denied that the results will not all tend towards efficient train service and economical haulage in the future?

So much for the general details of our improvements. Now for the principles by which we have been and are being guided, and the reasons for this doubling of tractive power and trebling of the capacity of goods wagons. The results attained are such as to give confidence as to the future possibility of economical haulage, in so far as train load is concerned. There are two further points to consider, which also influence to a certain degree the ultimate success. Geographical distance does not necessarily mean the cheapest route. We must and will see in a thorough examination of the relative rise and fall, curve and resistance, and climatic condition what the value of our haulage is by the different routes.

The Nature and Design of the Railway is one of the factors in haulage not to be lightly considered.

Finally, we have the question of the interest on capital, depending upon two factors—first, the cost of our works *in situ*, dependent upon economical methods and the price of labour; second, the cost of our materials. Rails and their accessories are a fixture, but I am not at all certain that we may not look to economies in the cost of our rolling stock. We have largely adopted pressed steel stock. It would appear to me that insufficient attention has been paid to the construction of steel trucks straight from the rolls or dies—namely, the possibility of their being assembled whilst still hot. Going even further it is impracticable to imagine the assembling of frames and sides in a heated condition in such a manner as to obviate the necessity of excessive rivetting. The hubs of our spoked railway wheels formerly necessitated the formation of some 20 welds. The

latest process presses the entire spoked hub whilst still hot in one process without a single weld. Similarly with locomotives it would seem that the application of similar principles might lead to economies in the construction of tenders.

Gentlemen, the title of my few remarks would have inferred dry details of the improvements to our rolling stock in South Africa, but these improvements are bound up with the principles of economic haulage, which I have roughly outlined to-day in order to show you the lines on which these railways are working; on their success will depend to a large extent the development of the industries of South Africa.

Railway rates may be necessarily used for taxation. On this matter I have no comments to make, but it surely behoves us to use every scientific endeavour to carry our goods at the lowest possible figure, laying thus on the governing power the duty of lowering such rates for the general benefit and development of the country.

In addition to our policy of high development of goods carrying capacity, we have been rightly called upon to improve our passenger services. Our local inheritance in passenger carriages was not a rich one. To-day, however, with the standards adopted, our railways will be enabled to compare more than favourably as to passenger stock with any lines in the railway world.

These are not, however, economies, except in the inducement to travel, which, in so far as our own lines are concerned, has amply justified our expenditure.

Gentlemen, it has not been possible for me to go into the details of improvement. On each and every heading I have mentioned, much might have been said covering a wide area of scientific engineering inquiries. It will perhaps be possible for some of our many eminent Railway engineers to amplify my poor outline of progress at some future meeting. In fact, a duty remains with them, for I feel sure that much of the future success of this portion of our Empire is inextricably bound up with the question of the economical and scientific treatment of railway communication.

## PARTICULARS OF WAGONS.

Railway.	Class.	Capacity.	Tare.	Lbs. Load per Lb. Tare.
BOGIES.				
C.S.A.R.	High Sided. Structural Section ..	60,000	29,600	2.03
G.N.R.	High Sided .. .. .	67,200	38,080	1.70
C.S.A.R.	Coal Hopper. Steel, American build	60,000	28,100	2.13
G.C.R.	High Sided .. .. .	67,200	30,900	2.17
M.R.	High Sided .. .. .	67,200	29,300	2.39
C.R.	High Sided .. .. .	67,200	28,600	2.34
C.S.A.R.	High Sided. Structural Section ..	70,000	30,268	2.21
C.S.A.R.	Coal Hopper. Structural Section ..	85,000	39,808	2.13
C.S.A.R.	High Sided. Pressed Steel ..	70,000	29,100	2.40
N.E.R.	Coal Hopper .. .. .	89,600	36,300	2.47
C.S.A.R.	Coal Hopper. Pressed Steel ..	85,000	36,500	2.33
P.R.R.	Coal Hopper .. .. .	100,000	39,000	2.56
C.S.A.R.	Coal Hopper. (Proposed) ..	100,000	38,000	2.63
P. & L.E.	Gondola .. .. .	90,000	33,500	2.68
C.S.A.R.	High Sided. (Proposed for 80-lb. Rail)	100,000	35,000	2.86
SHORTS.				
L.S.R.	High Sided .. .. .	36,960	16,800	2.2
G.N.R.	High Sided .. .. .	44,800	18,480	2.42
G.W.R.	High Sided .. .. .	44,800	19,040	2.36
C.S.A.R.	High Sided. (Proposed) ..	44,000	15,500	2.83

## 24.—DIAMOND DRILLING; PROSPECTING BY DRILLS.

By G. A. DENNY.

(Plates XV.—XXVIII.)

It has fallen to the lot of the writer to present to this Association some notes on the operation of prospecting by the aid of machine drills.

Machine drills for prospecting purposes have become a recognised media for the prosecution of research in the hidden depths of the earth, whether the object of that research be purely scientific, as in the Nile borings, or whether for the more sordid purpose of locating metalliferous and other deposits of economic value as in the gold and other prospecting borings in the Transvaal. The employment of prospecting drills for the collection of purely scientific data is, however, quite infinitesimal in degree when compared with its range of application to the more sordid and practical ends named, and I will therefore confine my remarks to this subject from the latter aspect.

The practice of drilling to great depths has been only comparatively recently in general vogue. Before the year 1870, so far as the writer is aware, no borings to greater depths than 250 ft. had been attempted. The industrial activity in the coal region of Pennsylvania, however, induced the search for the continuation of coal seams known to be outcropping at distant points, and as a consequence the first deep drill hole was projected and carried successfully through. The depth of this first deep hole was slightly over 750 ft. The engineer who designed the machine and tools for this work was the late M. C. Bullock, of Chicago, a man who played an important part in solving the engineering problems of drilling until his death in 1899, and whose name is a household word in every mining community. The writer was privileged to intimate acquaintance with Mr. Bullock, and embraces this opportunity of mentioning his name as the pioneer of deep diamond drilling.

Systematic prospecting by drills is not equally applicable to all classes of deposit. For the purposes of this paper these latter may be divided into the following classes:—

1. Stratified Deposits.
2. Irregular Deposits.
3. Alluvial Deposits.

Of all deposits found in nature, the most consistently regular are those included in the category of stratified deposits, principally for the reason that the matrix at least was formed at the same time as the enclosing rocks, and is indeed inseparable from them. This form is typified by coal measures, ironstone bands, oil-bearing strata, etc., in all parts of the world, and is specially represented in the Transvaal by the auriferous conglomerate beds.

or igneous origin, in the former as infiltrations or exfiltrations, and in the latter frequently as segregations.

Alluvial deposits represent the geologically recent erosion fragments of more ancient rocks, and are from their nature less permanent than the other deposits named.

From a prospecting standpoint there can be no question that the diamond drill is of greater general application in deposits of the first class named than in deposits of the second or third class mentioned, for the reason that stratified deposits cover greater areas; have more permanent relationship to the general stratigraphy; and are more regular in character. It follows, therefore, that the establishment of a valuable deposit at any point within a sedimentary area of given horizon, indicates the probability of meeting with similar conditions at other points within that area, and therefore a wide field is opened for the systematic application of the diamond drill.

It is otherwise with irregular deposits. These are, as the name implies, precarious both as to location and value. They may be rich and approximately regular in one description of rock, and commercially valueless in an adjoining rock of a different class. In such cases no defined programme of drilling over large areas is warranted, although in restricted localities the diamond drill may be invaluable in locating rich bunches or pockets.

In alluvial deposits the drill will locate the extent and direction of a deposit already known, but the generally patchy nature of the alluvial does not satisfactorily lend itself to a programme of drilling over wide and unknown areas.

The obvious deduction from the foregoing remarks is that the conglomerates of the Transvaal are peculiarly favourable subjects for exploitation by diamond drill, and the immense range of boring operations in this country proves that engineers have not been slow to avail themselves of the special facilities offered.

In the early history of the Witwatersrand there was naturally a legitimate conservatism amongst leading engineers on the subject of the permanence of the conglomerate deposits, as although deposits which the writer believes to be of similar nature had been worked in the Black Hills, Dakota, U.S.A., there was very little general experience as to their character.

Consequently the idea of prospecting the deeper levels by diamond drills suggested itself as a method of proving the continuity of the conglomerates, and in 1895 the first deep borehole was located about 5,000 feet south of the Main Reef outcrop in the Meyer and Charlton Mine. The average dip in the upper workings of the Meyer and Charlton is 45 degrees, and the difference in level between the borehole site and the reef outcrop is approximately 120 feet lower in the case of the former. A continuous dip of the reef throughout would have necessitated boring a hole 4,880 feet in depth. Fortunately, however, the

Irregular deposits may occur either in rocks of sedimentary

inclination of the beds becomes less in depth, and the South Reef was struck at about 3,150 feet, or, correcting for level at 3,270 feet, which shows the average angle assumed by a line drawn through the outcrop and the point of reef intersection to be about 33 degrees, which indicates that the angle of dip in the vicinity of the borehole does not probably exceed 25 degrees.

The results obtained from this borehole were returned as follows:—

		Thickness.	Value.
South Reef	... ..	5 in.	9.75 dwts.
Main Reef	... ..	15 ft.	1.00 dwts.
North Reef	... ..	6 in.	15.42 dwts.

Other important boreholes followed at different points along the Witwatersrand, and pioneered the way for the innumerable holes since put down. Amongst the pioneer boreholes may be mentioned the following:—

Vicinity.	Property.	Distance from Outcrop.	Depth to Reef.	Width of Reef.	Assay Values.
		Ft.	Ft.	Inches.	Dwts.
8 Miles East of Johannesburg	Rand Victoria ...	4,100	2,343	13	23.8
			2,391	9	23.8
2 Miles West of Johannesburg	Crown Deep ...	1,200	828	18	11.5
			895	18	275.0
			904	54	10.0
18 Miles West of Johannesburg	Lancaster ...	1,370	748	3	126.7
			784	30	27.8
22 Miles East of Johannesburg	Chimes Mines ...	4,340	1,738	4	14.0
			1,754	36	16.0

The generally favourable results obtained from these boreholes—which included a length on the reef of approximately 40 miles—set for ever at rest any doubt as to the permanence of the conglomerates in depth.

The writer attempted the preparation of a complete list of important boreholes for inclusion in this paper, but found it impossible to secure the necessary data owing to the fact that the publication of such information did not at present commend itself to some of the firms interested.

#### GENERAL OBJECTS OF DRILLING.

The first object of diamond drilling is to secure from the selected position a true section of the rocks, minerals, metals, etc., which together make up the formation. The diamond drill secures this to the operator by its capability of boring a continuous annular groove in rocks of any hardness, leaving centrally within the grove a solid section or core of the rock

passed through, which core is dislodged and removed to surface by suitable appliances. The diamond drill bores straight, smooth holes at any angle from vertical to horizontal, and may be used either on surface or under ground. It will, in quick time and at comparatively low cost, prove the thickness, value—to some degree—and extent of a deposit, much more cheaply than can be done by any other means, and is, in fact, a preliminary to the operation of development through shafts and drifts.

From the core produced by the drill an estimate can be made of the cost of shaft-sinking per foot, and the total cost to the horizon sought. Its use enables the engineer who is engaged in deep level mining to fix with certainty the depth at which the first cross-cut may be started from the shaft to the reef, and thereafter cross-cutting and sinking can go forward uninterruptedly.

If the information as to the horizon of the reef be not definitely settled, then there is danger of miscalculating the depth of reef, owing to possible faulting or change in the dip of the formation, in which case cross-cuts started out to cut the reef in an estimated position may prove to have been so much work and capital thrown away. The data secured by preliminary boring enables the engineer to figure closely on the hoisting and pumping requirements, and will also indicate, if more than one hole is sunk, the existence of faults of magnitude which will have to be considered in the subsequent development of the mine.

The present practicable range of diamond drilling may be placed at 6,000 feet vertical depth. At greater depths than this the practical difficulties of mining and the time and expense involved in development and equipment place any but deposits of unusual regularity and richness outside the pale of probable profitable working.

I propose in the following pages to divide my subject into three main sub-divisions, namely:—

1. The principal types of drills.
2. The operation of the diamond drill.
3. The cost of drilling.

#### THE PRINCIPAL TYPES OF DRILLS.

Prospecting machine drills may be divided into two great classes, namely:—

1. Rotary Core drills.
2. Percussive drills.

Rotary drills are most commonly employed in the search for mineral and metalliferous deposits or horizons, and percussive machines are generally used in seeking water, oil, and such-like strata.

The rotary class may be sub-divided into two sections, namely:—

1. Diamond cutting bits.
2. Steel cutting or chipping bits.



Of these the diamond cutters are largely in the majority.

The original drilling machine was equipped only with steel cutters, which were useful in the softer formations, but were quite unable to penetrate the harder varieties of rock. In course of time the hardest substance known was successfully applied to rock penetration, and gradually the diamond cutter took precedence over all other forms. In the early stage of drilling the practice was to secure large cores of the strata penetrated, the first diamond drills having been designed to cut cores up to 24 inches in diameter. But as the demand for carbonados grew, so proportionately the price per carat advanced, and in order to keep within reasonable cost it became necessary to reduce the number of carbonados employed, which also reduced the diameter of the cores.

The price of boring diamonds 30 years ago ranged from 20s. to 25s. per carat, and the highest price known to the writer in recent years was 280s. per carat, in 1896. The price subsequently fell to about 160s. per carat, but has again risen, the present ruling rate for first quality Brazilian carbonados being 300s. per carat, or say fourteen times higher than the average price 30 years ago.

The diameters of core as cut to-day vary with the depth of the hole. If a hole is designed to reach a depth of 5,000 ft., the first 1,000 ft. is bored big to permit of clearance, and the hole is gradually reduced in diameter as the work proceeds. The average diameter of a core from a depth of 5,000 ft. would be somewhat as follows:—

From immediate surface and to 50 ft. in depth,	3½ to 4 in. core.
From 50 ft. to 1,000 ft.	2¾ in. core.
From 1,000 ft. to 2,000 ft.	2 3-16 in. core.
From 2,000 ft. to 5,000 ft.	1½ in. to 1¾ in. core.

The hole bored will in each case be wider by that amount grooved out by the cutting face of the boring bit, and may be taken as 1 in. greater than the core diameter.

For shallow holes the core diameter may only be 1 in. For holes ranging between 1,000 and 3,000 feet, the upper sections of the hole are bored sufficiently large for clearance, but the final diameter will not exceed 1½ in.

A power drilling machine consists essentially of three parts, namely:—

1. The Engines.
2. The Feed.
3. The Hoisting Apparatus.

The larger sized machines of the well-known makes of diamond drill are generally fitted with duplex vertical engines, each maker having some special point of difference in design. Substantially the engine mechanism is the same in all makes, excepting in the smaller-sized machines, in which engines of the trunk piston type are sometimes employed.



The engines connect direct to a main drive shaft, which rotates the drill rods by means of bevel gears, and operates the hoisting drum by means of a spur wheel and pinion arrangement. The engines may be driven either by steam or compressed air, but the former is most generally used. Special machines operated by electric motors are also supplied for particular places.

The "feed" device of a diamond drill may be stated as that particular means by which the cutting bit is automatically forced forward as the rods are rotated. The most important varieties are the following:—

1. The Gravity Feed.
2. The Friction Feed.
3. The Positive Feed.
4. The Hydraulic Feed.

The gravity feed is the simplest of the feed devices, and is only applied in modern designs to hand diamond drills. The only mechanism involved in its application is a suitable connection to the drill rods, by means of which additional weight can be brought to bear on the cutting bit. Its usefulness, even in hand power drills, is limited to rocks of the lower scales of hardness.

The friction feed is applied by some makers to hand machines, and the smaller sized power machines, one of which, built by the Sullivan Co., is illustrated in Plate XVII.

The friction feed consists substantially of a system of differential gearing, driven by friction instead of positive action. The driving power from the drill-spindle to the counter-shaft is transmitted through leather washers on either side of a loose upper counter-shaft gear. In feeding, the gear and washers are pressed against a collar below them on the counter-shaft, by tightening a compressed spring. This spring is coiled in a sleeve, which is keyed to the counter-shaft above the upper gear. When the spring is compressed, the counter-shaft revolves with the upper gear and the washers, at a rate determined by the amount of compression on the lower counter-shaft turning the feed-nut gear, and as the amount of compression of the spring, and consequently the friction of the washers, can be increased or diminished at will, it follows that the feed can be varied up to any limit fixed by the proportions of the feed-gear.

The positive type of feed consists of an arrangement of differential gears, which causes a positive advance of the cutting bit at a rate determined by the particular gears engaged and the number of revolutions of the drill rods.

Plates XV. and XVI. illustrate this type of feed as used on some of the drills built by the Bullock Manufacturing Co.

The feed is obtained by varying the relative speeds of rotation of the hollow spindle (or quill) carrying the boring rods, and the bottom spur wheel N, the boss of which forms a nut fitting on the quill, which has a left-hand screw of four threads

per inch, as shown. It is evident that if both screw and nut revolve at the same speed there will be no "travel" of the screw, but if the wheel N be revolved more quickly the quill will travel downwards, and thus carry down the bore-rods with core tube and crown, the quill being rotated in the direction of the arrow.

The bevel-wheel W is driven by a wheel on the engine shaft. The quill slides freely in W, and is rotated by means of two feathers, which fit in key-ways, running the whole length of the quill.

The boss of the wheel is prolonged above the bearing, and carries three spur wheels, which rotate with it; these wheels gear with three other wheels running loose on the spindle A, which is hollow, and has a centre spindle carrying a key K, passing through long slots in the outer spindle, so that it may be raised or lowered, and thus engage with either of the three wheels, which will then cause the spindle to revolve. These wheels have an outer rim of wrought iron, in which the teeth are cut, and a centre of brass, one portion of which, L, is bored to fit the spindle, but has slots cut in it to receive the key K when required. Above and below L is a recess, in which the key may remain without contact with either wheel, and beneath the bottom wheel is a fixed plate, with slots—similar to those in the wheel—which lock the spindle when the key is lowered with them.

At the lower end of the centre spindle is another similar key passing through long slots in the outer spindle, and revolving in a recess in the body of the handle H. This handle can be raised or lowered, and fixed so that it engages the upper key, K, with either the locking plate or one of the wheels; or it may be in the spaces.

Assuming that the key is in the top wheel, the speed of feed will be one inch for 700 revolutions of quill, the ratios of speeds of quill and nut N being:—

$$\frac{44 \times 24}{42 \times 25} = \frac{1}{1.0057} = 700 \text{ revs. per inch.}$$

With the second wheel in gear the ratio is:—

$$\frac{41 \times 24}{39 \times 25} = \frac{1}{1.00923} = 433 \text{ revs. per inch.}$$

With the bottom wheel engaged the ratio is:—

$$\frac{38 \times 24}{36 \times 25} = \frac{1}{1.0133} = 300 \text{ revs. per inch.}$$

thus giving three different rates of feeding to suit the varying hardness of the rock.

It may be urged that the positive feed machine may be used in localities where, owing to shortness of water, it would be difficult to run a hydraulic feed machine. My experience is, however, that the quantity of water used in the running of the

one and the other amounts to practically the same thing, since all the water which is discharged from the hydraulic cylinder escape valves may readily be returned to the pumping sump without appreciable loss.

In combination with the positive feed arrangement the Bullock drills are provided with an apparatus called a Thrust Indicator, which registers the pressure at any moment on the boring bit. By carefully watching this instrument and recording its indications as the drilling proceeds, the pressures exerted upon materials of different hardness may be accurately determined, on a subsequent comparison of the core and the Thrust Indicator record. The experienced drill man will therefore not only be at once informed as to the hardness of the rock through which the bit is passing, but will at the same time regulate the feed gears to meet the conditions.

The hydraulic type of feed consists of an arrangement of cylinder and movable piston, the latter attached to a piston rod. Water under pressure is pumped into the cylinder either on the upper or lower side of the piston as may be desired, the direction being controlled by the manipulation of water valves provided for that purpose.

Two well-known power drills, the "Sullivan" and "Bullock," are equipped with this form of feed, the former having one cylinder, and the latter two. Fig. 1, Pl. XVIII., is an outside, and Fig. 2, a sectional, illustration of the "Sullivan" feed, which may be thus described:—

In this illustration, A is the hydraulic cylinder in which the piston B moves up and down with its attached piston-rod, C. A high-pressure pump is connected to the cylinder at the tee D, the water passing into and escaping from the cylinder through brass tubes F, and ports to which they connect, cast in the cylinder heads. The water valves 1 and 2 are the "inlet valves," and 3 and 4 are the "outlet valves."

To the upper end of the piston-rod is screwed a thrust plate G, through which pass three studs, screwed into another thrust plate, H. Between the thrust plates are two sets of friction ball bearings, one set on each side of a collar I, which is screwed fast to a drive rod, J. The collar I transmits the motion of the hydraulic piston to the drilling bit, for as the piston and piston rod descend they carry with them the two thrust plates, G and H, and the collar I. The drive rod J is rotated by a mitre wheel K, through which it slides, the feathers of the mitre gear sliding in grooves in the drive rod. The mitre wheel K is actuated by similar gear on the engine shaft. The collar I—moving in concert with the piston-rod C—being screwed fast to the drive rod J, rotates with it, and thus any movement of the piston is communicated to the piston-rod, and from that by means of the collar I to the drive rod, with the least possible friction. The drive rod is a hollow tube revolving within the piston-rod; to its lower portion, which projects beyond the

piston-rod, is screwed a chuck, L, which grips the boring tubes, F.

When in operation, water is pumped into the cylinder through the tee D. When the valves 1 and 3 are open, and 2 and 4 are closed, the water pressure is above the piston, and its downward motion is regulated by the manipulation of a valve on the escape tee E. Similarly, if the valves 2 and 4 be open and 1 and 3 be closed, the water pressure is below the piston, which consequently moves upward, the stroke of the piston being necessarily the continuous effective "feed" of the machine.

The water pressure upon the piston is indicated by a gauge placed between an outer admission valve and the tee D. It has been shown that the motion of the piston is communicated through the piston-rod to the thrust plates G and H, and again by them through the collar I to the drive rod J, which finally transmits it to the drill rods P through the chuck L. The engine in running, therefore, actuates the drive rod by means of the mitre-gear before mentioned, and the drive rod, clamped to the drill rods carrying the diamond bit, is, when boring, forced downwards whilst rotating, by the hydraulic pressure in the cylinder A.

The Bullock double cylinder feed operates practically in the same manner as the single cylinder feed. It is claimed that it gives a longer run of feed, keeps the spindle dead in line with the hole, eliminates side strains, and provides a duplicate plant, so that in the event of accident to one cylinder the other will keep the machine running.

The various "feeds" above described have each their supporters, but in the opinion of the writer the advantages of the hydraulic feed outweigh any that are offered by those otherwise designed.

In power machines the two feeds of importance are the positive and the hydraulic. The underlying principle of the positive feed is essentially a "constant rate of advance," as distinct from the underlying principle of the hydraulic feed, which is "pressure," which may be increased, or decreased, or remain constant for any length of time at the will of the operator.

The positive feed advances at a rate determined by the proportion of the gears, and that rate of advance must be maintained whether the rock be hard or soft. It is clear that if a drill passes suddenly from a soft to a very hard formation, and if care be not exercised to change the gears to suit the harder rock, the rate of feed may outrun the cutting capacity of the diamond bit, resulting in overheating, abrasion, and possibly heavy loss. Contrariwise, if the machine be drilling in a hard rock and suddenly passes into one more easily cut, or into a fissure, the boring bit will still only advance at the rate determined by the gears, and the machine, in the hands of an inattentive runner, may in the one case only be performing a

small proportion of the work of which it is capable, and in the other be doing absolutely no drilling at all.

In the case of the hydraulic feed these dangers are practically non-existent. The boring bit being advanced by a constant pressure will automatically make greater advance in softer formation, whilst in the passage from softer to harder formation there is no immediate danger of damage to the boring bit, seeing that it is not arbitrarily forced forward a distance proportionate to a given number of revolutions of the engine as in the case of the positive feed. If the hydraulic feed machine strikes a fissure the piston cannot suddenly drop in the cylinder, being sustained on water, which can only discharge itself at a rate under the control of the operator.

The importance and desirability of the unlimited range of feed which is provided by the hydraulic principle is, I think, obvious. There are doubtless many rock formations of such unvarying hardness that the positive feed machine would hold its own against its rival, but, granting that, the fact remains that the hydraulic feed will perform that work equally well, and if required in another position where the conditions are different it will more readily meet the change.

The hoisting apparatus in all power drills is substantially the same, consisting of a drum operated from the engine by gears. The hoisting drum is fitted with speed-reducing arrangements to enable the heaviest loads to be handled with ease, sometimes four different speeds being available. Besides this the drum is used in "chopping bit" operations, in driving the casing pipe, etc. For these purposes the drum is run continuously in one direction. A rope is turned a few times round the barrel, and by manipulation the rope grips on the drum and lifts the working tool. At a certain height the rope is allowed to slacken on the barrel, the tool then falling by gravity to accomplish its work.

For holes of great depth, say 5,000 ft., special arrangements have to be made for hoisting. It is necessary, in order to reduce the weight of the rods in a hole of this depth, to work with gradually lessening diameter, otherwise they could not sustain their own weight. Even with the taper arrangement the weight of a line of rods 5,000 ft. in length is about 20 tons.

To handle weights of such proportions a hoist is provided, which is equal in carefulness of design to the best mine hoists. The engines are provided with a link motion, enabling the operator to lower the drill rods into the hole under steam pressure.

On the smaller machines band or other friction brakes are provided.

The more important accessories of a diamond drilling field equipment may thus be tabulated:—

*Drilling Machine.*—Complete with engine and hoist. Pl.

XX. shows a complete Sullivan drill ready for work.

*Steam Boiler.*—Complete with feed pumps, fittings, pipe connections, etc. Pl. XX. shows a usual type of boiler.

*Steam Pump.*—The uses of this pump are for pumping water into the borehole through the drill rods, out through the boring bit and back to surface through the clearance space between the drill rods and the sides of the borehole. The position of the pump is shown in Pl. XX. The water performs the functions of keeping the boring bit cool, prevents the silting of the hole, and brings the borings to surface for inspection.

*Derrick.*—This is generally a four-sided tubular frame, as depicted in outline in Pl. XXI., at the top of which is a sheave pulley, over which passes the hoisting rope. It is built as high as practicable in order that the drill rods may be disconnected in lengths of 40 or 50 ft. In the case of shallow boring, a short tripod frame is used, when the rods must be disconnected at intervals of 20 ft. at most. Platforms are provided in the derrick for use when handling the drill rods, during the operations of hoisting and lowering.

*Drill Rods.*—These consist of stout flush-jointed tubes, the diameter of which varies according to the diameter of core required. In soft formation and for coal borings, cores 6 in. in diameter may be desired, whilst in gold formation the diameter may be under one inch. A section of a Sullivan drill borehole is shown on Pl. XXII., Fig. 1.

*Boring "Bit" or "Crown."*—This consists of a short metal shell, made from specially selected material, into the face and sides of which are set the diamond cutting stones, as illustrated in Pl. XIX., Figs. 1-6. It is made with a shoulder, and is provided with channels for the passage of water.

*Carbonados (Diamonds).*—The most generally used black diamonds, or carbonados, are derived from the Province of Bahia, Brazil. They occur in association with the gem diamond in placer deposits, and are highly valued all over the world for their abrasive properties. The most useful weight stone for drilling purposes is about 3 carats, and about eight stones are set in the average boring bit. The stones are arranged in the boring bit at equal intervals, four being set as "outside" stones and four as "inside" stones. "Outside" and "inside" in this connection relates solely to the projections of the stones, as to whether they give clearance outside the bit—between it and the outer periphery of the borehole—



or inside the bit—between it and the cored material. The “setting” of the stones in the metal bit is compassed by first boring a receptacle hole in the bit, and after carefully fitting the stone into the hole, leaving the necessary cutting projection, to caulk it tight either with copper or other malleable material. Frequently no extraneous caulking is introduced, the metal bit itself affording the caulking medium.

*Core Lifters.*—This appliance, shown in Fig. 2, Pl. XXII., as its name implies, is employed for the purpose of raising the core that has been cut by the drill. It is so designed that it moves easily over the core whilst the drill is advancing, but immediately the rods are lifted in the hole the core lifter is pressed into a tapered recess, which causes it to grip tightly on the core and break it from the solid. Any core which has passed into the core barrel is safely held in position there, until released at surface. The core lifter most generally employed is a taper split ring, in the inside of which are projections for gripping the core.

*Core Shells.*—The core shell is a short tapered tube, which holds the core lifter in position. The core shell is screwed on at one end to the boring bit, and at the other to a connection for attachment to the core barrel.

*Core Barrel.*—This piece of steel tubing is of short length for shallow holes and up to 30 ft. in length for deep holes. The average length is 10 ft. Its function is to hold the core as the drill advances, and its length obviously determines the longest run that can be made without lifting the rods to surface. Sometimes the drill runner is fortunate enough to strike formation that cores easily and solidly, when he waits until the core barrel is full before raising the rods; at other times the drilling may be in fragmentary rock, which causes jamming in the core shell or core barrel, necessitating frequent lifting of the rods and consequent loss of drilling time.

*Stand Pipe.*—This is a tube, generally from 3 to 5 inches in diameter, placed in the top portion of the borehole. It serves to prevent leakage in the upper loose rock or alluvium, and also for collection of the returned borings pumped from the borehole. It is also called “drive” pipe.

*Drive head and shoe.*—These are attachments for the drive pipe, and are used in forcing it through soft ground.

*Casing pipe.*—This is tubing passed inside the stand pipe, to prevent loss of water through fissures, and also to prevent caving of the hole in bad ground. If casing pipe has to be used at depth the bore-hole

must be reamed out to a diameter large enough to take it.

*Reamer.*—This consists generally of an extra heavy tube attached to the drill rods and having a hollow boss, set with carbons, for the purpose of enlarging the borehole for casing. It is also used in cases in which the gauge of the crown has been set too narrow, leaving too little clearance for the drill rods, and returning water.

*Hoisting Plug.*—This is a screwed eye bolt, which turns freely in a socket screwed to a threaded boss, which fits in the drill rods. In lowering or raising the rods the hoisting rope hook engages the eye bolt of the hoisting plug.

*Water Swivel.*—This is an attachment to the top of the drill rods when boring, and is the means of connection between the pump and the rods.

*Other Appliances.*—In addition to the foregoing, there are devices for holding the drill rod securely; recovering taps for drawing jammed or broken rods or casing; augers for use in soft ground; chopping bits for breaking down boulders met with in driving the stand pipe, and sundry items too numerous to mention here.

#### ROTARY DRILLS.

Thus far I have been describing diamond rotary drills. I now propose to briefly refer to one special rotary drill, which employs steel cutters in lieu of diamonds.

The most important drill of this type is one known as the Davis-Calyx, which originated in Australia. The cutter in this machine is a cylindrical-pronged shell. The end of each prong is made into a cutting point by shaping the cutter end of the prong back at about an angle of 50 degrees with the direction of the prong. The teeth when blunt are heated and sharpened up by hand hammer, as shown in Pl. XXIII. The cutting bit is attached to the core barrel, which latter is of the same outside diameter as the shell of the cutter. The core barrel is attached by means of a reducing plug to the drill rods. The "Calyx" (cup-shaped), which is a special feature of this machine, is a tube of the same diameter as the core barrel. It surrounds the lowest drill rod, and rests on the reducing plug between the core barrel and the drill rods, thus making at the bottom a practically closed tube. At the upper end of the tube it is open, and the space between the drill rod and the enclosing tube forms the Calyx. In the sectional view, Pl. XXIV., water is pumped down inside the rod, and then passes through the cutting teeth, carrying with it the detached particles of rock chipped out by the cutter. The water and chippings are forced upwards by the pump, on the outer side of the cutting bit and core barrel,



and whilst passing in this restricted space the water has such a velocity that it is impossible for the cuttings to settle. After passing the Calyx tube in its upward flow, the water reaches a comparatively large space, where the rate of travel is much lessened, and consequently the solid chippings from the cutter drop out of suspension, and are caught in the Calyx. In this manner a record of the chippings is retained, and can be examined in connection with the core.

In operation the drill rods are slowly rotated; the cutting teeth being on the bottom of the hole. Pressure is exerted on the cutters, which causes them to bite or grip into the rock. The drill rods are continuously revolved, and eventually the torsion strain on the rods overcomes the resistance due to the bit of the cutting bit, when the latter spins round and chips a groove in the rock, leaving the solid core standing. The cutting bit presently comes to rest again, and as soon as the rods have accumulated sufficient energy to overcome its resistance the spin of the cutting teeth again takes place, this operation being repeated throughout the boring.

In rocks of exceptional hardness it was found that the steel cutters progressed so slowly that it was decided to employ a diamond bit for negotiating them. This alternative was perfectly satisfactory from a drilling standpoint, though too costly as compared to the steel cutter boring, and eventually a system was perfected by which chilled steel shot was substituted for the diamonds, with successful results. The chilled steel shot is used with a specially designed bit, and is so hard that it will scratch glass.

In drills wherein no "Calyx" is used it has been found that the pressure due to pumping removes the shot from its position in the bottom of the hole, but the Davis drill has demonstrated the practicability of using chilled shot, for the reason that the pump pressure can be so greatly reduced owing to the increased size of the hole in its upper portions.

The great feature of this machine is—if the claims made for it can be substantiated—that it will bore holes of comparatively large diameter as rapidly and much more cheaply than is possible to drill holes of small diameter with the diamond drill, owing to the high price of diamonds. The small cores produced by diamond drills have been reduced to the minimum because of the excessive cost of carbons used in the boring bit. Originally all boreholes were drilled comparatively large in diameter, and the Davis-Calyx drill attempts to get back to first principles by producing a core of large dimensions.

It is claimed by the makers that they have demonstrated in practice that the combination of steel cutters and chilled shot will satisfactorily penetrate rocks of any hardness, and it is specially claimed for this machine that it is not liable to be deflected by crevices met in the boring.

The cost per foot for chilled shot in the hardest ground is

said not to exceed 1d. per foot, as compared with an average of 15s. to 20s. per carat when using carbons at current prices.

This machine stands potentially to-day as the only rival to diamond drills. It has not yet been seen in operation on the Witwatersrand, but within a short period, the writer understands, it will enter into competition on these fields.

#### PERCUSSIVE DRILLING.

This is a type of drill distinct from the rotary machine, which I have described. It consists essentially of an outfit arranged for chopping or churning, and the main differences between this and rotary drills is that from this machine no solid core can be obtained. It is generally used in the coal districts of America for testing coal-bearing strata, but frequently the indications obtained from it have led to disappointment. The only record of strata passed through which it gives is presented in the shape of cuttings returned to surface, but it has been found impossible to distinguish the churnings in carboniferous shales from the indications obtained when passing through true coal seams, and frequently capital has been launched in a prospective coal enterprise which has proved by subsequent development to be merely black shales.

This form of machine finds its greatest usefulness, perhaps, in prospecting for oil and water, in which field of inquiry it holds its own to-day.

#### THE OPERATION OF A DIAMOND DRILL.

The first consideration in connection with diamond drill operations is the site of the borehole. In all cases in which it is impossible to get data, bearing upon the formation in which it is proposed to operate, careful attention should be paid to the likelihood of meeting with faults or dykes, or such other phenomena, which might interfere with the boring investigations. In unexplored districts and in areas over which rocks of later formation obscure the particular horizon to be explored, there is often nothing to guide the prospector as to dangers of fault and dyke which may exist, and consequently the risk of meeting with these drawbacks has to be run.

The boring site should be chosen—as far as may be consistent with the conditions of the deposit and the boundaries of the property—with a view to accessibility by wagon or otherwise, and with due regard to the water and fuel supply, and in such a position that it is not liable to be flooded by heavy rains or sudden rushes of water.

Having finally fixed the boring site or sites, the next thing necessary is to erect the drilling plant, excavating at the same time a hole for catching the returned water from the borehole.

After the drilling gear is all erected and connected, the stand pipe is placed in position. This pipe must pass through all surface alluvium or broken rock and be properly bedded in

the solid rock. Its purpose is to prevent waste of water in the upper surface soil or rock, and also to collect and deliver the rock cuttings and chippings—which are carried up by the pump pressure—at such a point that the drill runner can observe the nature of the rock through which he is passing.

Having secured the stand pipe, the next operation is to place a piece of casing inside the stand pipe to make a water-tight joint. A hole for the casing is bored and reamed, and the casing is subsequently lowered and fixed. Boring may now begin.

The drill rods, having the boring bit, core barrel, core shell, and core lifter attached at the lower end, are lowered inside the casing to the solid rock. The water swivel is attached to the top length of drill rod, and this rod is passed through the drive rod of the machine, and connected to the other lengths in the hole. The rods are then gripped firmly by screwing up the chuck on the machine, and, all connections having been made, the hoisting drum is thrown out of gear and boring begins. When the drill has advanced so far—assuming no stoppages—that the core barrel is full, the drill is stopped, the water swivel removed, and a safety clamp for holding the rods suspended in the hole, grips the drill rods below the first joint. The chuck screws are then loosened, and the top rod is drawn out through the upper end of the drive rod.

Various arrangements are made by different makers of drills to throw the machine out of gear in order that perfectly free hoisting of the rods may be done by the drill runner.

The rods in the hole—of whatever depth—are hauled up gradually by the hoist, and parted at their screwed connections into lengths dependent upon the height of the derrick. The rods are 10 feet each in length, and if the derrick be sufficiently high, a “parting” is only required as at the end of every fifth rod. When the last rod, to which is connected the boring bit, core barrel, etc., reaches surface, the shell is unscrewed from the barrel, and the core extracted. The drill must be run slowly for the first 50 ft. in depth, in order that the boring bit may not diverge from the vertical direction, which it is liable to do if there are fissures or planes of bedding into which it can easily penetrate.

The boring bit at any time should not be run at more than 175 revolutions per minute, if only for the reason that at high rotative speeds there is a liability to set up grinding of the core upon itself, in the core barrel, and the more friable portions of the core are lost. In metalliferous deposits the richest portions of the ore are generally the most easily reduced by attrition, and an unsatisfactory borehole result might be traceable entirely to the loss—in the manner indicated—of the richest section of the deposit penetrated by the drill. An appliance has recently been patented by the use of which it is claimed no

grinding of core can take place in the barrel. It is pivoted at the top on a universal ball joint, and allows the outer core barrel to rotate freely around it. If successful it should prove a valuable addition to drilling appliances.

#### AVERAGE RATE OF BORING.

The average rate of boring varies as to the depth of the hole, the character of the rock met with; and freedom from accident—whether unavoidable or otherwise.

The depth of the hole affects the rate of boring because of the additional time required to hoist and lower the drill rods as the hole increases in depth. This does not refer especially to the longer time required to do the hoisting pure and simple, but to the increased time taken to lift the rods; to part them at the lengths determined by the height of the derrick; to stack them in a convenient place; and, after emptying the core-barrel, and replacing the boring bit, to lower them back into the hole, length by length as they were parted in hoisting. I may note here that it is better practice to keep two core barrels, in order that the core can only be extracted by the core-taker, and is not subjected to the scrutiny of the drill runners.

The time required for hoisting and lowering rods from and to a depth of 1,000 ft. is about two hours, whilst from a depth of 3,000 ft. the time required is about 7 to 8 hours. This time is, of course, quite lost as far as drilling is concerned, and therefore the deeper the hole and the more frequently the rods require to be hoisted, the greater will be the reduction made in the average rate of boring.

The character of the rock met with relates to two features, namely its hardness, and its liability to fragmentation in coring. The ideal features are a rock easily bored, which at the same time cores in long lengths. If a rock cores in a fragmentary manner, there is great liability for it to obstruct the drilling by sticking in the core shell and the core barrel, and therefore even at a depth of 3,000 ft. it happens that the rods must be hoisted after boring 6 inches or less, which obviously seriously affects the average rate of drilling. In a good coring rock, and with a 30 ft. core barrel, the drill rods may only require to be hoisted when the core barrel is filled, or once in every 30 ft. bored.

The accidents to which a drill is liable are numerous, relating to those which are unavoidable by reason of breakage in the gear and those which are avoidable by care on the part of the runner.

The gear breakages may refer to the engine, hoist, rope, pump, drill rods, jaw clamp, etc., and any one of these may cause serious loss and delay, whilst some may cause the entire loss of the borehole, rods, and boring bit. The last would specially refer to breakage of the hoist, the rope, or its connections; stripping of the screwed ends of the drill rods; or failure

on the part of the jaw clamp to hold the rods whilst in the process of hoisting or lowering. Any of these causes might result in the rods dropping from a great height in the borehole, and subsequent impossibility of recovering them; although with the appliances now at the command of the drill runner it is seldom that the wrecked rods cannot be withdrawn. In any event, however, a long time is required for the recovery of the rods, leading to direct loss and reduction of the average rate of boring.

The avoidable causes of delay—apart from carelessness in the running of the plant—refer especially to silting of the borehole, jamming of the rods, or too great pressure on the boring bit. Silting can only occur if through want of attention on the part of the runner the rods are lowered into the borehole before the pump is started, or in case of a mud-rush whilst the pump is stopped. The special value of a hydraulic feed is shown in such a case, as the rods may be worked up and down at the will of the runner without stopping the engine.

Jamming can occur through bad setting of the boring bit, which reduces the gauge of the hole and allows no clearance for the rods. A heavy deflection of the bore-hole may also cause the rods to jam.

Too great pressure on the boring bit results in heating the carbons, chipping or tearing them out altogether; and in subsequent loss of time in "fishing" for the stones with a bit filled with beeswax. Such accidents have a direct effect upon the average rate of boring.

A most frequent source of delay in boring is the loss of water in the borehole, which is at once dangerous to the boring bit, and a cause of loss of information to the drill runner, inasmuch as the rock chippings are not returned to the surface for his inspection, and in localities where water is scarce, might lead to the abandonment of the hole. The reason for the water loss is the presence of fissures in the rock. These difficulties can often be overcome by introducing cement, corn-meal, or sawdust into the hole, but if these fail, it is necessary to ream and case the hole to the depth of the fissure and beyond, a process which in some instances would be more costly than the starting of an entirely new hole.

The rate of boring in average Witwatersrand conditions for a hole 1,000 ft. in depth might be placed at 25 to 30 ft. per day. For holes 2,000 ft. in depth the rate would be from 17 to 22 ft. per day; for holes 3,000 ft. in depth, from 13 to 17 ft. per day; and for holes 3,500 ft. in depth, from 10 to 13 ft. per day. These averages make allowance for all ordinary delays, but do not include the extraordinary delays which are previously described. The average drilling rate of a number of Witwatersrand bore-holes is given in a table attached to this paper.

## SIZING UP BORE-HOLE RESULTS.

It is axiomatic that bore-hole results, on the Witwatersrand at least, should be accepted rather as proving horizon than value. A bore-hole, after all, will only sample a very fractional part of the area under exploration, and the results which it gives may for the following reasons be very unsatisfactory, if not entirely misleading:—

1. It may pass into a dyke from which it cannot emerge within reasonable depth, as in Pl. XXV.
2. It may pass into a dyke which causes an overthrust of the mineralised or metalliferous body sought, as in Pl. XXVI.
3. It may pass through a fault plane on which the body sought is displaced, as in Pl. XXVII.
4. It may be deflected by a hard plane underlying reef matter, as in Pl. XXVIII.
5. It may strike a portion of the body sought which is wider or narrower, richer or poorer, than average.

(The writer has been unfortunate enough to experience cases 2 and 3 in bore-holes on the Rand.)

In the first three cases no definite conclusions could be arrived at, either as to horizon or value, and the whole capital and time sunk in the undertaking would have been wasted. In the fourth case the apparent width and value of the body would be greatly exaggerated, as the drill might possibly core 10 ft. of valuable material in places where there is only an actual thickness of 3 or 4 inches.

In the fifth case the consequences might be either over-estimation or under-estimation of the area under test.

The obvious deduction is that more than one hole should be bored in testing an area. Such a policy provides a safeguard against the unsatisfactory experiences which have been enumerated; gives data for figuring approximately the dip and strike of the deposit; and indicates any great faults which may exist between the bore-hole sites. In all instances in which it is possible the boring programme should be prepared beforehand and the holes started simultaneously, thus avoiding the loss of time which accrues if for any cause one of the boreholes is lost, or yields only negative results.

During the boring operations the cores should be carefully examined by experienced men, and a proper log book kept of all rod drawings, stoppages, loss of core—in fact, every item of interest. In cases in which the drilling is not a contract job, careful records should be kept of labour, stores, fuel, repairs, time, etc. The drilling records recommended by the writer are shown below, the Log Book being kept in the drill-house and the Core Book in the core-house.

CORE BOOK HEADINGS.

Date.	No. of Draw.	Depth of Hole.	Depth Drilled in Run.	Length of Core Recovered.	No. of pieces of Core Recovered.	Length of pieces of Core Recovered.	Diameter of Core.	Class of Rock.	Depth at which Rock changed. FromTo	Estimated Dip of Rock.	Assay Value.	Engineer's Remarks.

LOG BOOK HEADINGS.

Date.	No. of Draw.	Time Drill Stopped for Hoisting.	Time Hoisting.	Time Lost before Lowering began.	Time Lowering.	Time Drilling Re- started.	Depth of Hole.	Depth Drilled in Run.	TIME LOST.				Total possible Drilling time per Hole.	Total actual Drilling time.	Per. centage of Time lost.
									Fuel	Water.	Breakdown (indicate nature)	Various (specify Items).			



The strata passed through should be carefully noted and transferred to a proper diagram drawn to scale, whilst the core itself should be preserved for comparison or inspection at any future date. Dips of strata arrived from the stratification planes of core are very hazardous, and at most only guesses, which in the case of deflection in the bore-hole would be utterly wrong. This can only be arrived at accurately from a series of bore-holes in unfaulted country, when data is furnished which can be used mathematically.

In sizing up data from boreholes it will therefore be understood that there must necessarily be great reliance upon the judgment and experience of the person acting in an advisory capacity. Comparisons of rocks requiring expert opinion are necessary, and a knowledge of the general stratigraphy and of the special features of the valuable body sought. Without these qualifications in addition to the ordinary attainments of an engineer, no reliable deductions are possible, when boring deep holes in geologically difficult country. More especially it should be recognised that values obtained from bore-holes on Witwatersrand formations, whether good or bad, should be accepted with all reserve, and with due consideration to other factors which enter into the case.

#### COST OF DRILLING.

The cost of diamond drilling may be divided into the following items:—

- White labour.
- Native labour.
- Carbons.
- Water.
- Fuel.
- Transport, erection, and dismantlement of drill.
- Maintenance.
- Reaming and casing.
- Depreciation.

*White Labour.*—A drill requires three white men to operate it, namely, two runners and a foreman, who is also the diamond setter. A fourth man to take charge of the core is usually employed. The wages of the foreman will be from £40 to £60 per month, and the drillers are usually paid £30.

*Native Labour.*—The natives required generally number four, namely, one on each shift for firing the boilers. The average cost of natives, including food, is £4 per month.

*Carbonados.*—The cost per foot drilled for carbons varies directly as to the nature of the rock, and the care and skill of the diamond setter and drill runners. The boring bit is set generally with about 20 carats of carbon, and in free cutting rock one setting of the crown may last 50 ft. or more, whilst in ground badly fissured and of a flinty nature the crown may have to be re-set every 10 ft. of boring. This statement does not



mean that the total weight of carbons will have been used in the distances named, but only that by abrasion the cutting edges will have been ground away, and a fresh setting will be required to keep clearance in the hole. The actual wear of carbons varies, of course, with the conditions attending the boring, and may range between a carat in 10 ft. to a carat in 50 ft. On the Witwatersrand the average is probably one carat for every 15 to 20 ft. bored.

The cost of carbons varies directly as to the demand. The whole produce of Bahia, Brazil, passes through the hands of one firm of dealers, and is a virtual monopoly. The causes—apart from demand—operating to keep carbon high in price are the scattered nature of the diamondiferous deposits, the low yield, and the laborious methods employed in the collection of the stones. No response can therefore be made to sudden heavy demands, with the result that the price per carat is a very fluctuating quantity. The writer has known variations in the past 12 years between £5 and £15 per carat. The price at the time of writing is about £15 per carat. A loss of 1 carat for every 15 to 20 ft. would therefore amount to approximately £1 per foot drilled.

*Water.*—Water is a *sine qua non* of diamond drill operations. Steam power being used in most cases, water is required for that purpose, and it is essential in the boring operations proper, for the purpose of keeping the boring bit cool and for returning the rock cuttings to surface.

The cost for water necessarily depends on its locality—with reference to the bore-hole site—and the quantity required. It may be plentiful and near at hand, or scarce and distant. If plentiful and close there is no need to conserve it with great care, if scarce and distant every precaution must be taken to save it.

The quantity of water required for a drilling outfit capable of boring a 3,000 ft. hole would be somewhat as under:—

For boiler (to supply steam to drill, pump, etc.)	... ..	3,000 gallons per day
For drill rods (allowing that all except 15 per cent. of the water pumped in is returned to sur- face)	... ..	12,000 gallons per day
Total	... ..	15,000 gallons per day
If the water is lost in a fissure and the pump is run at average speed the quantity required per day would be	... ..	80,000 gallons per day

No allowance is made for the water used in the hydraulic cylinder, as that may be caught and re-used without loss.

No estimate of water cost of general application can therefore be made.

*Fuel.*—The cost for fuel per foot drilled depends upon the quality of coal, the transport cost, the price for coal at the pit mouth, and the rapidity of the rate of drilling.

For a machine capable of drilling a hole 3,000 ft. deep, the fuel consumption might be reckoned at from 15 to 20 cwt. per working day. If wood fuel be available the quantity required is 2 to  $2\frac{1}{2}$  times the weight of coal.

*The Cost of Transport, Erection, and Dismantlement* of the drilling plant and outfit to and from the boring site, must be made a charge against the borehole. A small machine can be erected complete with derrick, house, etc., in about four days clear, and no machine should take longer than a week to get into working shape.

The cost per foot drilled of these operations will naturally vary as to distance, accessibility, and method of transport.

*Delays.*—This item cannot be figured upon. Delays may be caused through attempts to prevent loss of water in the borehole; jamming or breakage of the drill rods; loss of carbons in the bore-hole; breakdown in the engine or hoist. These delays, besides being costly in themselves, involve in some cases the purchase of new parts, thereby adding to the expense.

*Maintenance.*—This item must be separately figured in each case. It covers repairs and renewals to the working parts of the machine, and is in some bore-holes a heavy charge per foot drilled.

*Reaming and Casing.*—If it be found necessary for any reason to increase the diameter of the bore-hole, reaming is resorted to, an operation performed by a special tool set with carbons. Again, if fissures or badly standing ground be encountered, which it is thought advisable to case with tubing, the hole must be reamed an increased diameter to take the casing. The cost of reaming and casing per foot will sometimes exceed the original cost of boring. Each particular case must be separately treated, and therefore no cost figures can be estimated for general application.

*Depreciation.*—As a diamond drill plant is subject to severe usage, its cost should be written off at the rate of 20 per cent. per annum. A heavy equipment on the Witwatersrand would cost £5,000, and the monthly charge for depreciation would be at the rate of, say, £85 per month.

The following bore-holes and data were supplied to the writer by the courtesy of the firms interested:—

## BORE-HOLE PARTICULARS.

Locality.	Distance from outcrop or Hospital Hill shales.	Depth to Reef.		Total Depth of Hole.	Diameter of Core.	Time occupied in boring.	Average progress per day.		Cost per foot drilled.	
		ft.	in.	ft.	in.	days.	ft.	in.	ft.	s. d.
Mudlertfontein, Borehole No. 1	7,300	2,973	0	3,000	1½	185	16	9	0 to 1,500 1,500 to 2,500 2,500 to 3,000 3,000 to 3,500 0 to 1,500 1,500 to 2,500 2,500 to 2,781 2,781 to 3,503 0 to 1,500 1,500 to 2,500 2,500 to 3,000 0 to 1,000 remainder	30 0 25 0 30 0 35 0 20 0 25 0 30 0 35 0 20 0 25 0 30 0 37 6 42 6 50 0 50 0 50 0 50 0 50 0 50 0
Mudlertfontein, Borehole No. 2	6,900			3,503	1½	241	14	6		
Mudlertfontein, Borehole No. 3	7,100	2,804	0	2,806	1½	186	15	10		
Grootvlei, N.E. of Greyling- stad	8,800	420	0	1,541	1½	88	17	46		
Middelvlei	11,300			1,641	1½	94	17	46		
Grensboekfontein	11,300			2,806	1½	197	14	55		
Venterspoort	11,300			2,400	1½	116	21	47		
Grensboekfontein	13,000	1,972	42	8,254	1½	188	16	34		
Grensboekfontein	13,500			3,112	1½	203	15	33		
Labaton				2,712	1½	210	12	91		
Grensboekfontein §	12,700	1,677	08		1½					
Cliversfield Road	10,800	2,097	10			months.				
Cliversfield West	9,300	1,964	0			11	0	0		42 0
						8	7	0		40 0
New Rip East	5,000	2,039	0			days.				
Randfontein Deep †	2,430	5,000	0			132	15	4		40 0
South Randfontein Deep	1,550	2,781	0	3,425	1½	514	0	7		50 0
						208	16	4		43 6

‡ Quarries and Shales.

§ Not yet completed.

† Reef not cut in hole probably due to deviation.

The above information was obtained from a 3.000 ft.  
hole drilled at the location of the well in a property  
which is owned by the same owner.

The above is a copy of the original station is in the Coal  
is covered by a thin Water is con-  
siderable in quantity and is in the

The above information is being furnished to you for your information and is not to be used for any other purpose.

**WILLIAMSON COUNTY**

[illegible]

**Figure 1**

100

**Figure 6**

**RECEIVED**

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**THE UNIVERSITY OF CHICAGO**

*[Signature]*

1. What is the purpose of the study?

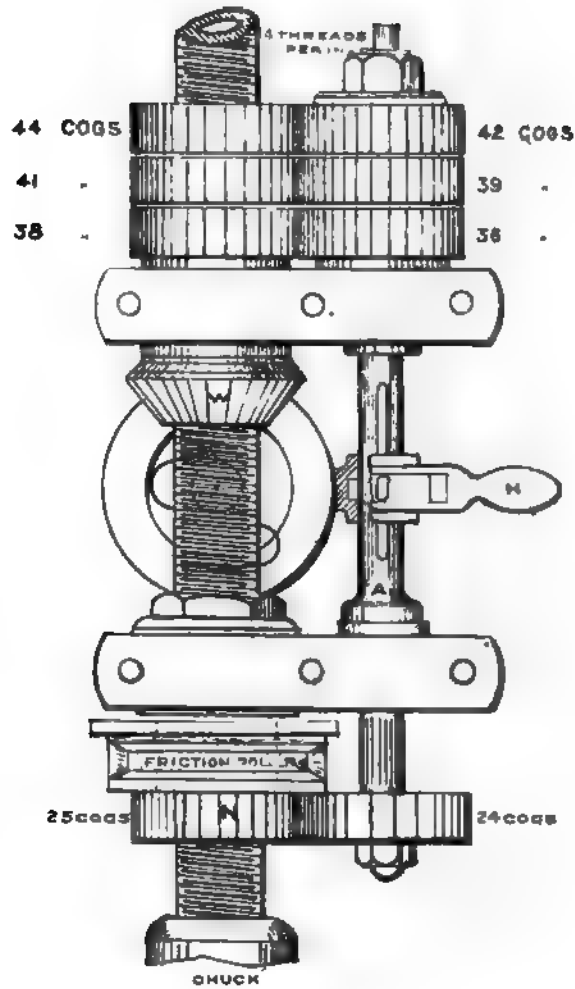
11. *Chlorophyll a* and *Chlorophyll b* contents were determined by spectrophotometry using the following equations:

\_\_\_\_\_

100-443887-100

1. *Journal of the American Medical Association*, 1997; 277: 1033-1038.

1. The first step is to identify the problem or issue that needs to be addressed. This involves gathering information and understanding the context of the problem.



*Outside View.*  
*Bullcock's Positive Feed.*

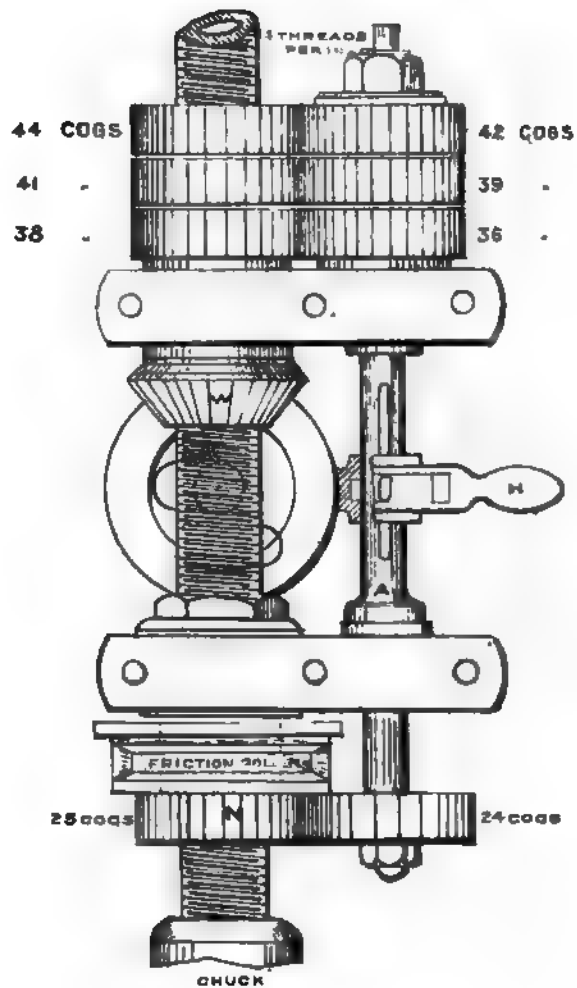
The following figures show some itemised costs of a 3,000 ft. bore-hole sunk on the Eastern Witwatersrand on a property with which the writer is connected.

The distance from the railway station is 14 miles. Coal is conveyed by a wagon a distance of 14 miles. Water is conveyed by wagon a distance of one mile.

The formation consists in the upper sections of the hole of fragmentary cherty rock and diabase, and in the lower sections of quartzite and diabase.

White Wages	amounted to	£2,216	equal to	14.80s.	per foot.
Native Wages	„	£323	„	2.15s.	„
Fuel	„	£507	„	3.38s.	„
Water	„	£208	„	1.38s.	„
Carbons (average cost £13 per carat)	„	£2,993	„	19.95s.	„
Boring Bits	„	£50	„	0.33s.	„
Oil and Repairs	„	£203	„	1.35s.	„
Casing and Reaming	„	Nil.		Nil.	
Total		£6,500	or	43.34s	per foot.

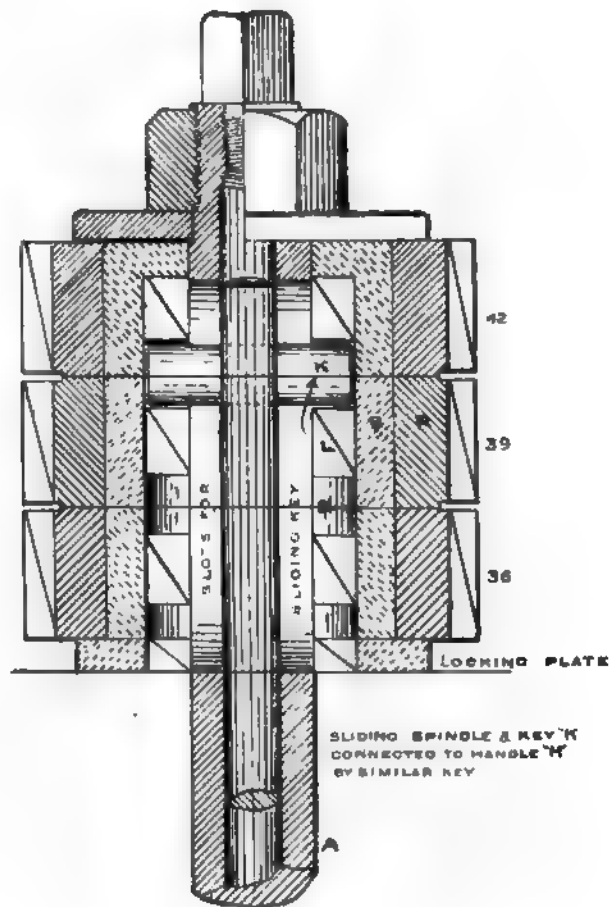
In this hole 1 carat of carbons bored only  $13\frac{1}{2}$  feet.



*Outside View.*  
*Bullock's Positive Feed.*

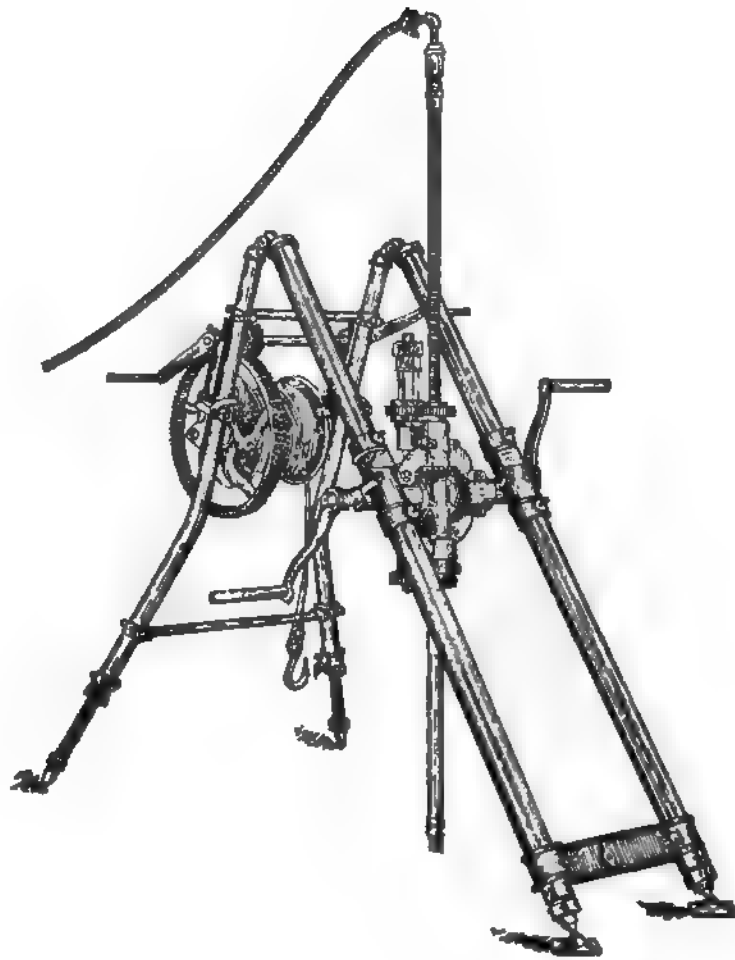






*Sectional View.*  
*Bullock's Positive Feed.*

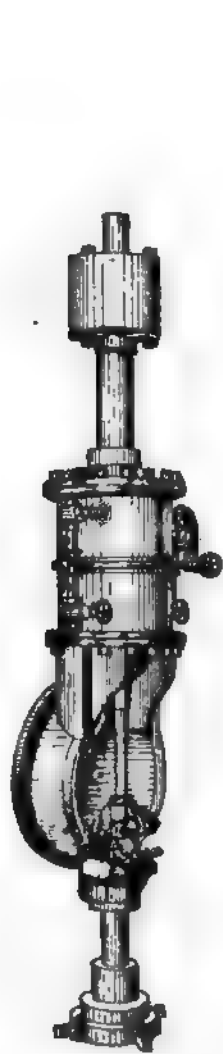




*Hand Drill fitted with friction feed.*

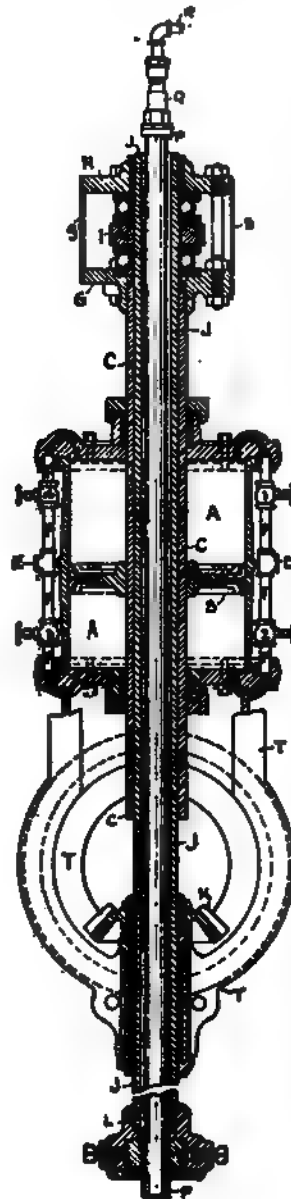
**G. A. Denny: Diamond Drilling**





*Fig 1*

*Outside view  
Sullivan's Hydraulic Feed.*



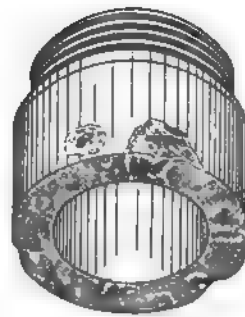
*Fig 2*

*Sectional view  
Sullivan's Hydraulic Feed.*





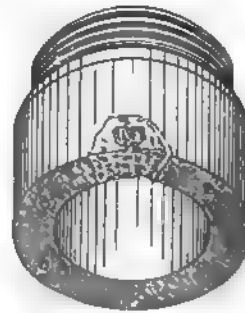
*Fig. 3*  
Bit with recess bored.



*Fig. 6*  
Bit set complete  
for drilling.



*Fig. 2*  
Bit marked for position of Carbons.



*Fig. 5*  
Bit with Carbon  
Caulked.



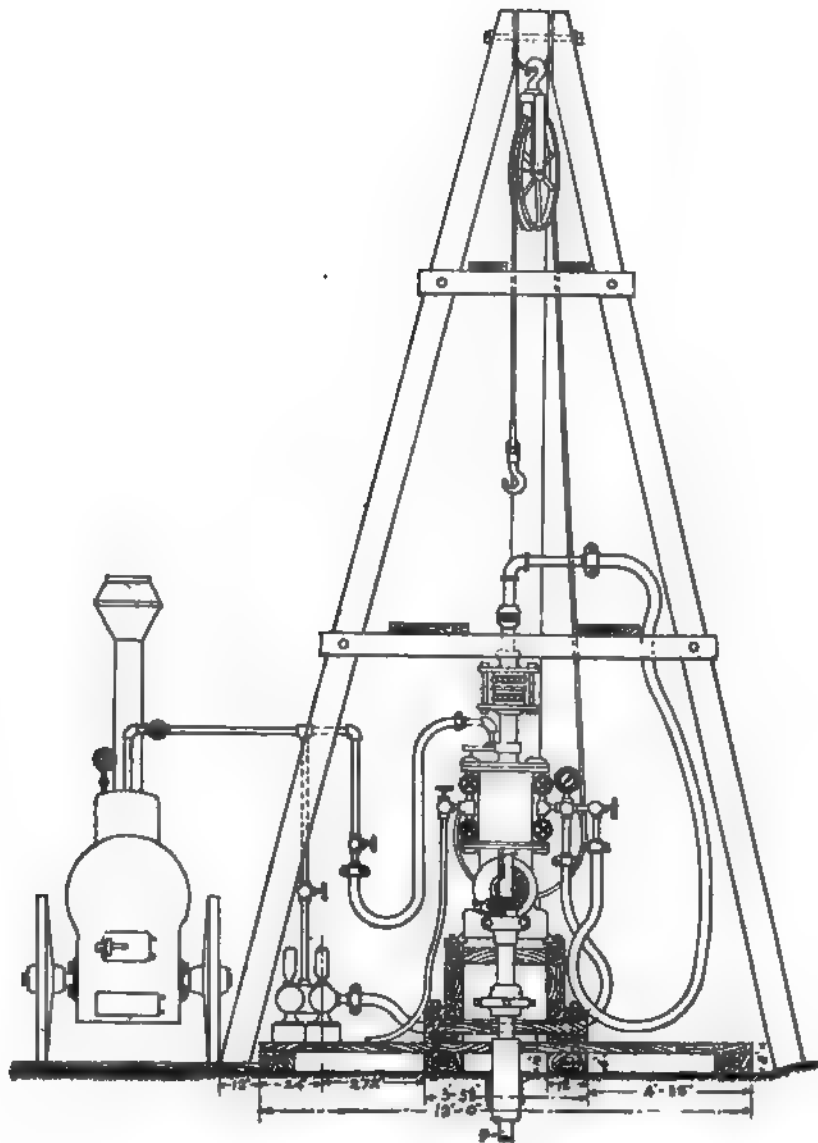
*Fig. 1*  
Blank Bit.



*Fig. 4*  
Bit with Carbon set  
ready for Caulking.



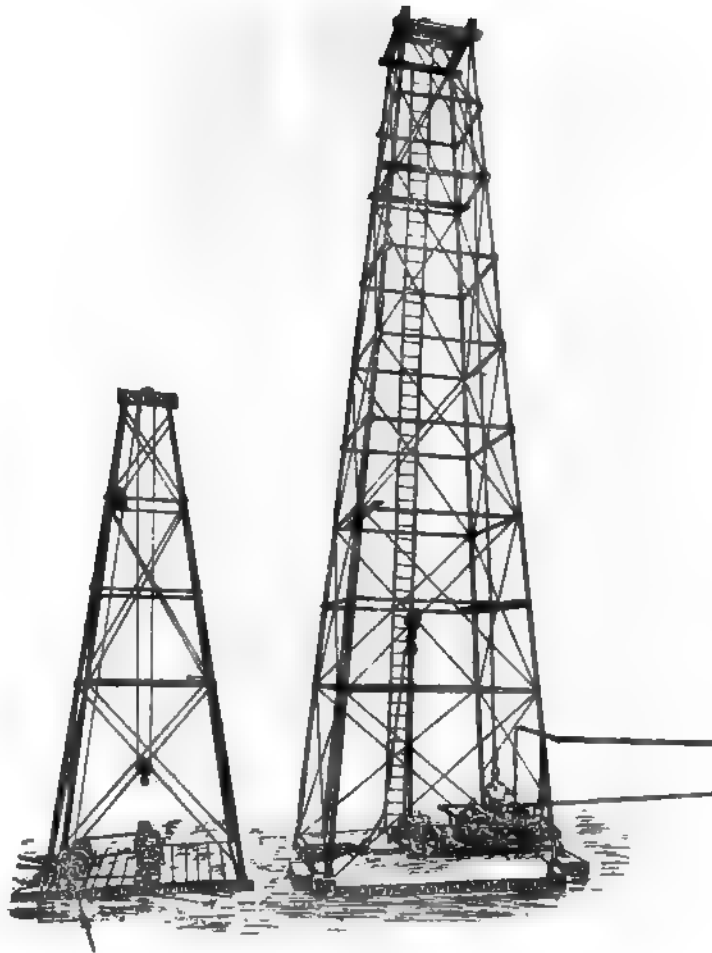




*Sullivan Drill complete and ready for work.*

**G. A. Denny. Diamond Drilling**

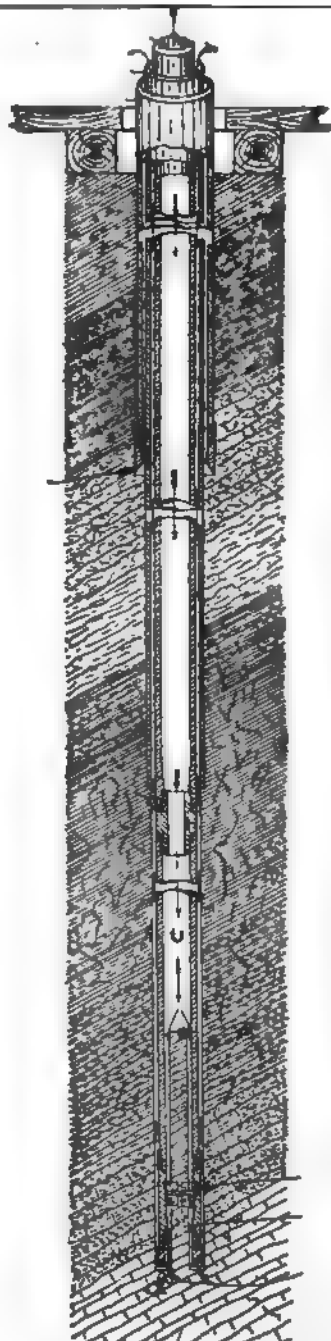




*General view of Drills and Derricks.  
Davis Culyx Drill.*

*G. A. Denny: Diamond Drilling*





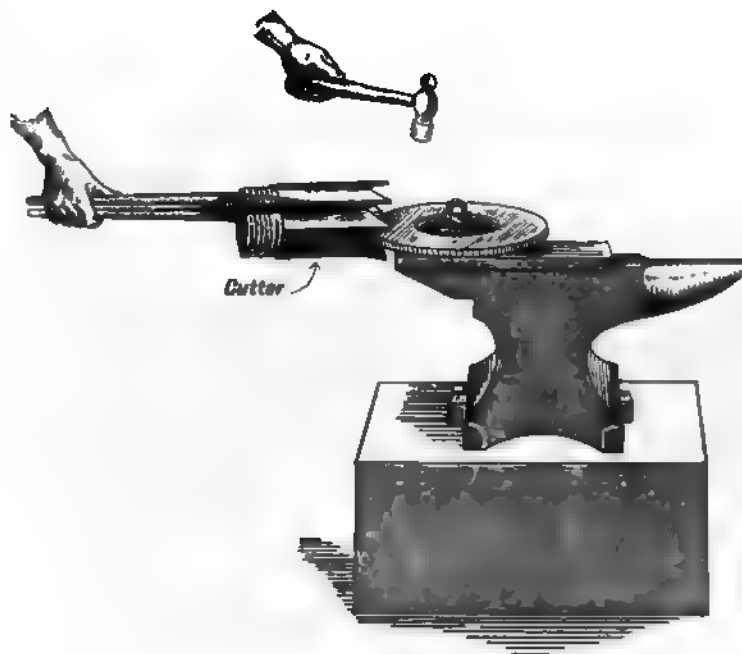
*Fig 2*  
Core Lifter.

- |                |              |                  |
|----------------|--------------|------------------|
| N. Stand pipe. | <i>Fig 1</i> | M. Casing tube.  |
| P. Drill rod.  |              | U. Core barrel.  |
| O. Drive shoe. |              | W. Core breaker. |
| V. Core Shell. |              | X. Boring bit.   |

*The arrows show the direction of the water in the Bore-hole.*

**G. A. Denny: Diamond Drilling.**

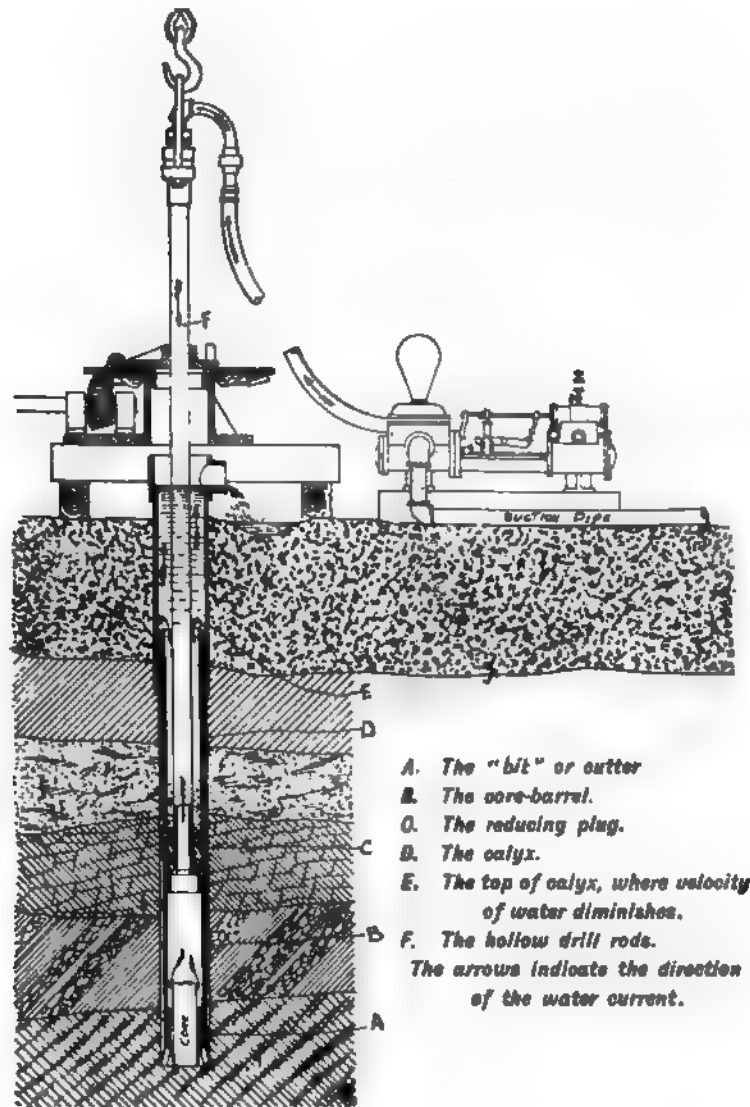




*Sharpening a Davis cutter.*

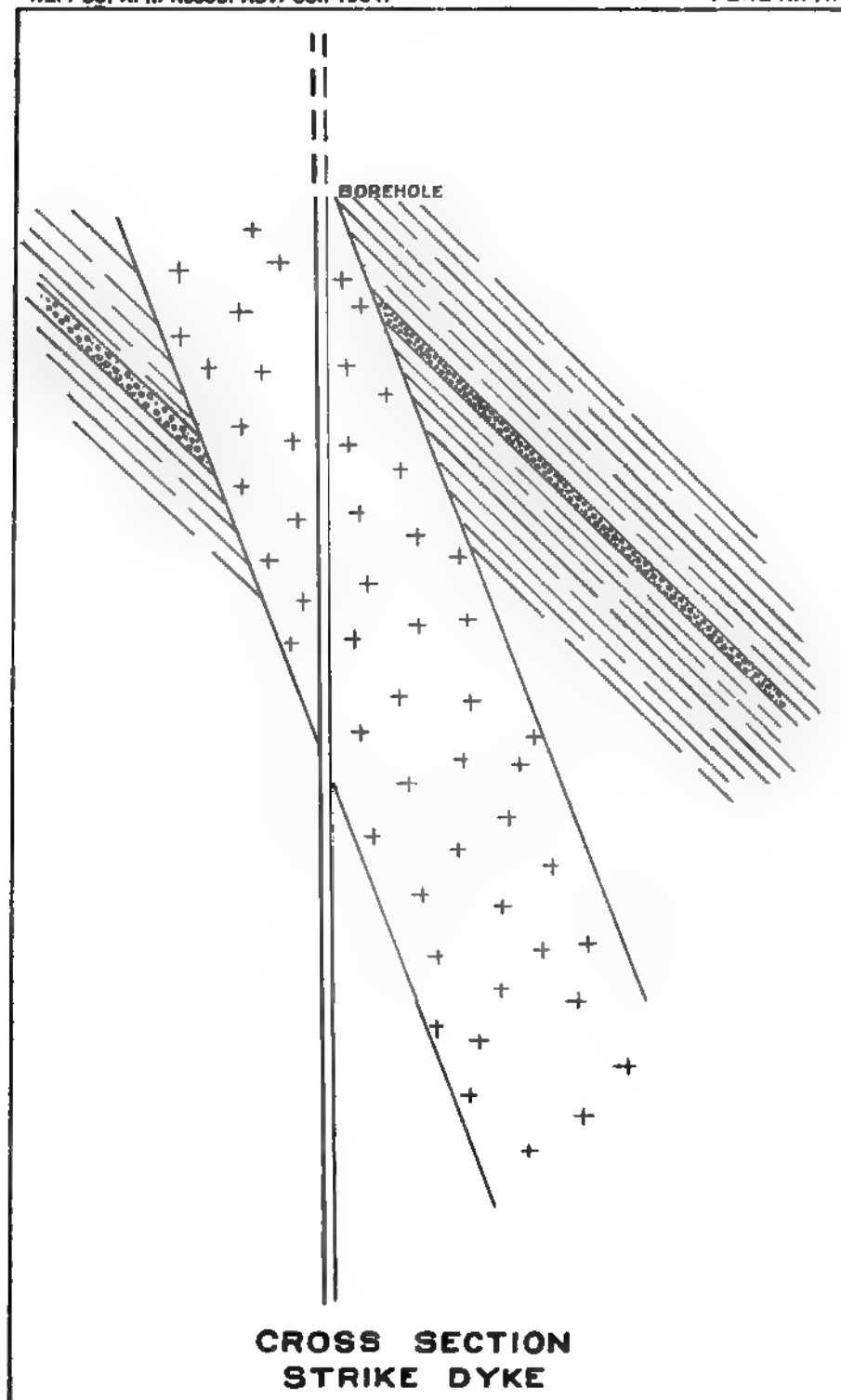






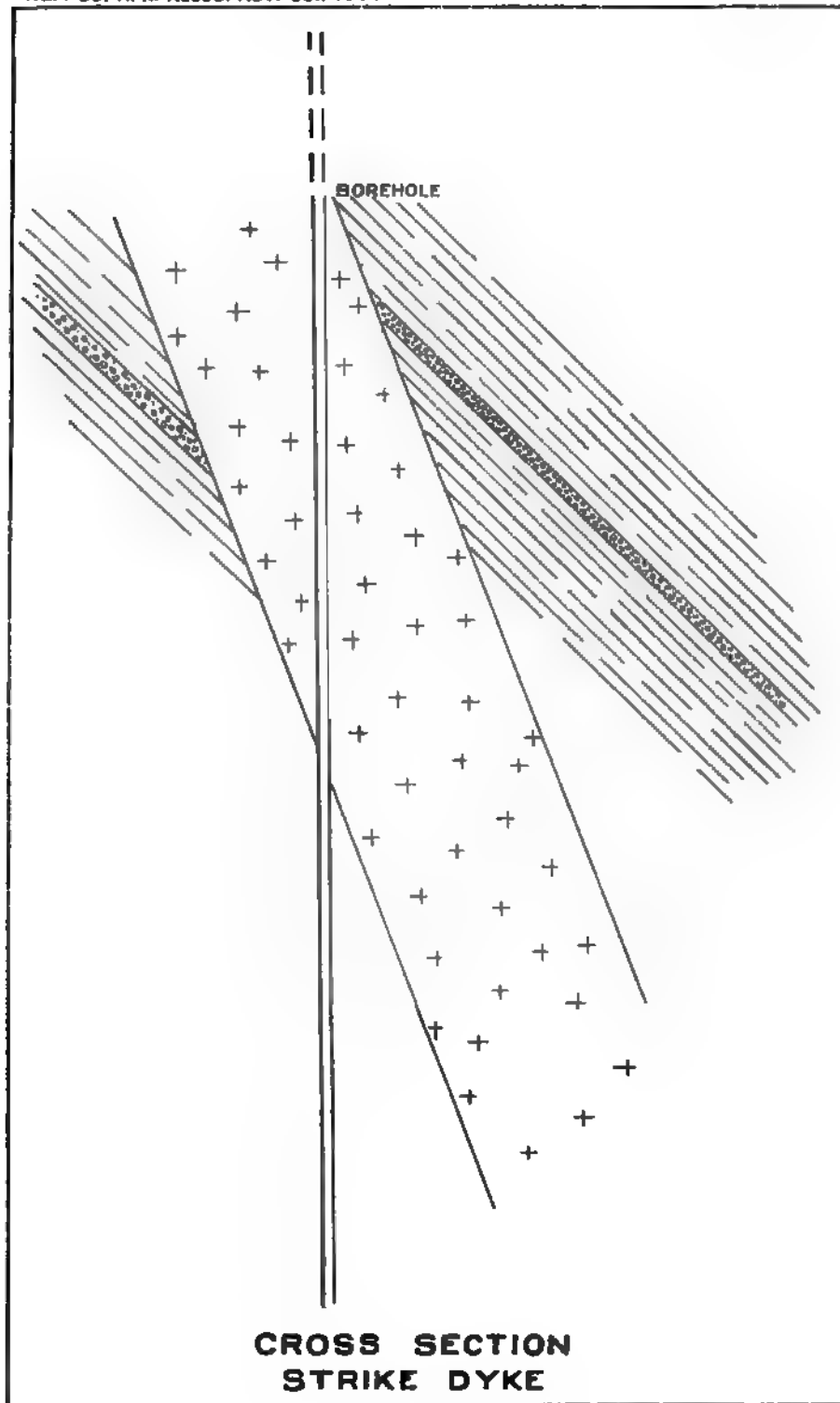
*Sectional view of Davis Calyx Drill  
 in operation.*





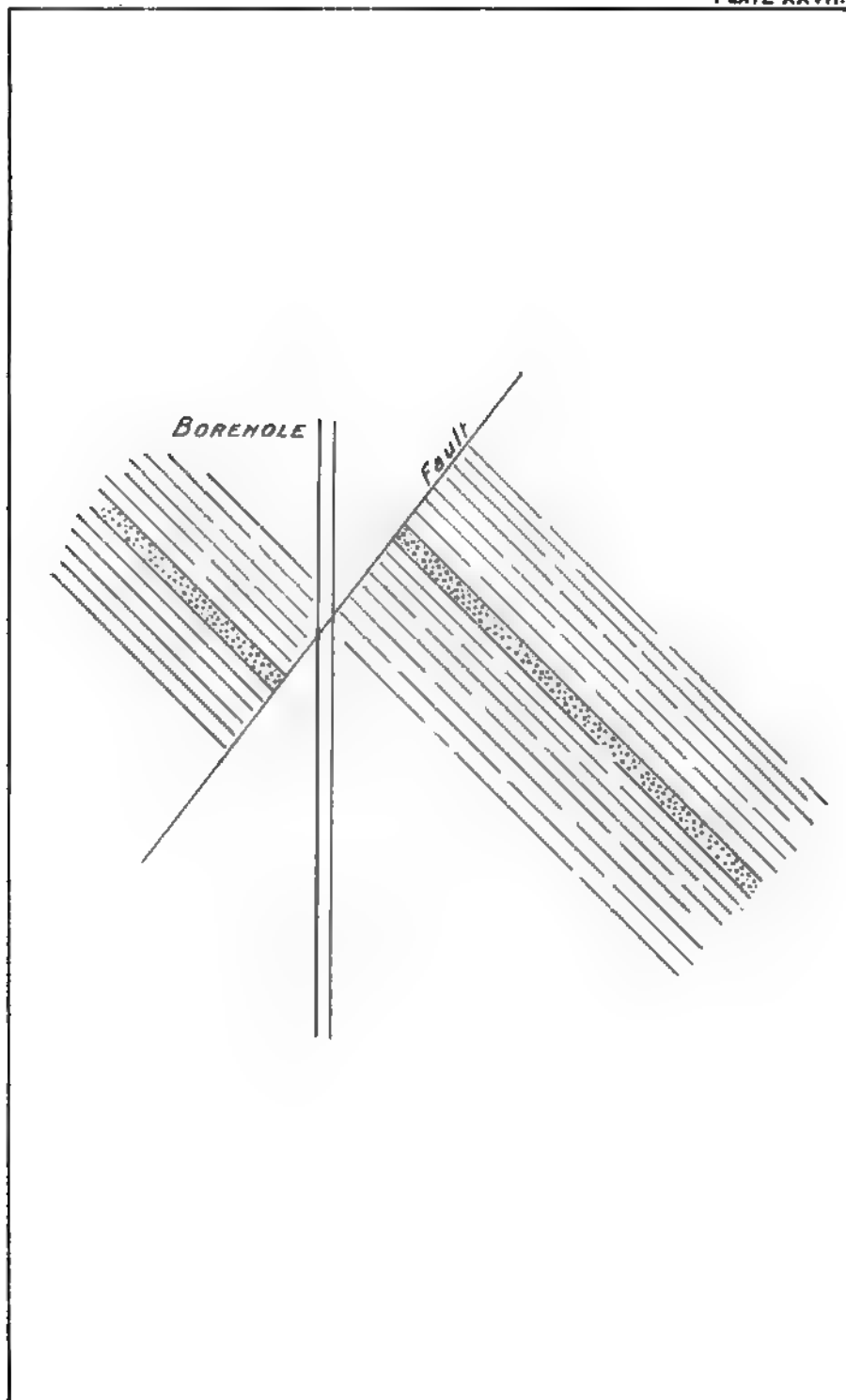
*G. A. Denny: Diamond Drilling.*





*G. A. Denny: Diamond Drilling.*

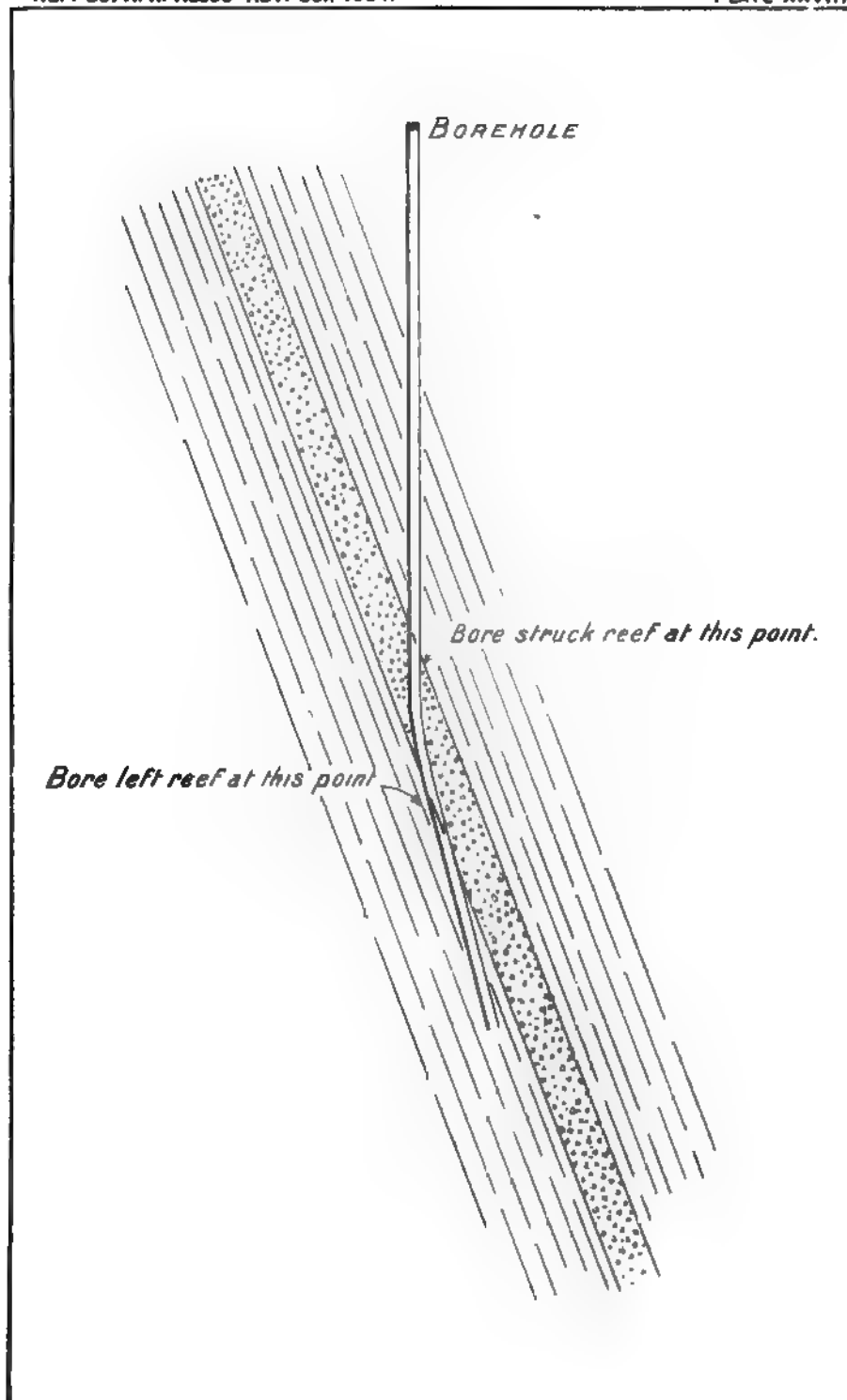




*G. A. Denny: Diamond Drilling*







*G. A. Denny: Diamond Drilling*



## 25.—HYDRAULIC SLUICING AND DREDGING FOR GOLD.

By J. H. RONALDSON, M.E.

(Plates XXIX.—XXXI.)

It would be impossible within the limits necessarily imposed on a paper intended for this Association to enter into a detailed description of the subject, and the more salient features only will be sketched. The utility even of bringing this subject before a South African audience may possibly be questioned, and it may be objected that there is little ground in South Africa possessing the richness and character requisite for the successful application of systems of mining unequalled in cheapness. In opposition, however, to this possible view, it may be urged that it took Australia sixteen years to follow the lead of New Zealand in dredging, and, although it has been the unfortunate duty of the writer during much of the past two years and a half to advise others against entering on dredging projects in different parts of South Africa and of Madagascar where conditions did not happen to be suitable, it cannot be assumed that no suitable ground exists in either place. It is the hope of the writer that this short paper may prove of some slight interest and use to others who may have come in contact with ground in the country amenable to treatment by one or other of the methods to be described.

It will be evident that the processes under review are applicable not only to alluvial gold, but to stream tin and to diamondiferous alluvial deposits.

It is not an unreasonable assumption that the gold first used by man was won from alluvial gravels, and that only later as art advanced step by step falteringly, through the long ages, were the stores of golden grains locked by nature in her rocky storehouses brought under contribution. It is, moreover, undoubted that the bulk of the gold found throughout the world was, till within quite recent times, the product of alluvial digging, and, as there is nothing new under the sun, it needs no great stretch of imagination to picture a miniature "alluvial rush" in primæval times, when the matter of disputed claims was settled by the expert use of the shinbone of an ox or of a smooth pebble from the brook. It is known that as far back as 1100 B.C. the Phœnicians were working the gold placers of the Guadalquivir in Spain; possibly they even knew of the "banket" formations in that country.

It appears, however, to have been reserved for modern times to witness "alluvial rushes," which dislocated the framework of society and sucked into their wild vortex individuals from all countries, of all colour, of every creed, and of any or no trade or profession. Such were the rushes to California, Australia, and New Zealand, scarcely more than half a century ago, when sailors deserted their ships in San Francisco and Mel-

bourne, when poets and bill-posters, schoolboys and veterans, tradesmen, labourers, professional and cleric, intoxicated with anticipation of wealth, braved endless privations in a mad rush for the goldfields. Vast as have been the quantities of gold so won, the richest and the best of these diggings have had but an ephemeral existence as "diggings," but to the countries in which they occurred the result has been deep and permanent. Reef-mining, agriculture, and commerce have dogged the footsteps of the hardy alluvial pioneer, and country has been thereby opened up and developed with a rapidity probably never equalled.

The comparatively rapid exhaustion of the rich alluvial gravels accessible to the digger, and the wealth amassed, acted as an incentive and provided the means for attacking the large deposits of gravel too poor to repay the individual digger with his simple and crude appliances. From this point we have the evolution of hydraulic sluicing, to be followed later on by dredging.

The treatment of alluvial deposits for the winning of gold is in general effected by the following three methods:—

- (a) By alluvial miners or "diggers" making use of pick and shovel and simple gold-saving appliances, such as the dish or pan, the cradle, or a rudimentary sluice-box in conjunction with water; also on rare occasions by the use of dry-blowing apparatus when water is unobtainable and the yield of gold is high, as was the case in the early days of Coolgardie and Kalgoorlie, in Western Australia.
- (b) By hydraulic sluicing.
- (c) By dredging.

#### HYDRAULIC SLUICING.

In its original form, and, where applicable, hydraulic sluicing provides the simplest and cheapest method of recovering alluvial gold. Water supplies at once the power for breaking down and disintegrating the gravel deposit, the medium for the separation of gold from gravel, and the vehicle for transporting the débris.

The essential conditions for its successful application in its simplicity are, first, a large supply of water at a considerable elevation above and capable of being brought within a reasonable distance of the working point, and, secondly, a sufficient fall or get-away for the débris. An absence of one or both of these conditions has led to the introduction of ingenious modifications whereby the deficiency may be made good; and we may conveniently classify the system and its modifications as follows:—

- A. Hydraulic sluicing with a natural head of water and sufficient fall for a clear get-away for the débris.
- B. Hydraulic sluicing with a natural head of water and a hydraulic elevator, but without a clear get-away.

- c. Hydraulic sluicing with a natural head of water and a water-driven centrifugal pump elevator, but without a clear get-away.
- d. Hydraulic sluicing with an artificial head of water, and with sufficient fall for a clear get-away.
- e. Hydraulic sluicing with an artificial head of water, without fall for a clear get-away, and with a centrifugal pump elevator.

Methods A, B, and C necessitate a large water supply at considerable elevation. It seldom occurs that such a supply is found in close proximity to the deposit, and it is usual to tap some stream or streams at a sufficient elevation, and lead the water in a channel or "ditch," with a fall of from 6 to 20 feet to the mile, and following the contour of the hillsides to a point above and as close to the work as practicable. These head races or ditches are sometimes of extraordinary length, as in the case of the Milton Ditch in California, which was 84 miles long. Particulars of a few Californian ditches are given in the following Table A:—

TABLE A.  
\*EXAMPLES OF CALIFORNIAN DITCHES.

—	Length in Miles.	Width in Feet		Depth in Feet.	Grade in Feet per Mile.	Cost.	Discharge in Cub. Ft per Second.
		At Top.	At Bottom.				
North Bloomfield ...	55	8.65	5	3½	16	£ 93,340	80
Milton Company ...	84	7.6	4	3½	12 to 30	92,600	75
Eureka Lake ...	18	—	—	—	—	51,000	62
San Juan & Branches	45	—	—	—	—	58,598	32
Excelsior Smartville	33	8	5	4	9	—	42
La Grange... ..	20	9	6	4	7 to 8	90,000	60

The greater part of La Grange ditch is cut in granite.

From the end of the ditch the water is led in thin wrought iron pipes from 16 to 24 inches or more in diameter down the hillside to a "Giant" or "Monitor," provided with a nozzle which may vary from 1¼ to 6 inches in diameter. The "Giant" has a swivelling movement horizontally and vertically, and throws a jet with tremendous force wherever required against the gravel bank. The velocity of flow from a nozzle under various heads of water is shewn in the following table:—

\* A. J. Bowie, Jun.

Head of water in feet...	50	100	150	200	250	300	350	450
Velocity of jet in feet per second	... 57	80	98	113	127	139	150	163

*Method A.*—Where a good fall exists the water and the gravel are led away in a sluice cut in the bedrock and pitched with cobbles or wooden blocks. The gold is caught between the interstices of the paving, which is taken up at intervals in order to collect the gold. It is a common practice to pour a quantity of mercury into the sluice-box.

Where an insufficient fall exists, methods B and C may be employed, and in both cases a portion of the water is used as the motive power in elevating the débris and the water already used for breaking down the gravel.

*Method B.* The hydraulic elevator in essence consists of a column of pipes placed more or less vertically with the lower end leading from a sump-hole into which the broken down gravel is swept, and with the upper end delivering on to an elevated sluice-box. A jet of water from the power column is introduced to the lower end through a specially constructed pipe and nozzle. The rush of water from the nozzle is sufficient to suck up the water, gravel, and gold from the sump-hole and force the mixture upwards through a constricted and hardened throat-piece and the rising column to the elevated sluice-box.

By this process water and gravel can be elevated from 10 to 15 feet for every 100 feet vertical of the power column.

*Method C.*—The centrifugal gravel pump has been evolved from a long course of experience in Australia, and is noticeable for the special form given to the runner, the renewable hardened internal lining, the remarkable resistance to wear and tear, the general high working efficiency and the large amount of material it can treat. The actuating power in *Method C* is obtained through a Pelton wheel fixed on the pump shaft, or on an independent shaft, and driven by water from the main power column. As in the preceding method the gravel and the water are sucked from a sump-hole and elevated through a rising column of pipes 12 to 15 inches in diameter to an elevated sluice-box.

A convenient arrangement, and one which the writer adopted for use in a flat river valley in Portuguese Manicaland, is to mount the pump and Pelton wheel on a pontoon to facilitate changing their position from point to point as work progresses.

In this and in the preceding method the débris is stacked on a spoil heap, which usually occupies a space from which the gravel has been previously hydrauliced.

*Method D.*—It not unfrequently happens that auriferous or tin-bearing deposits occur in elevated positions, to which it is practically or economically impossible to lead a water supply for simple hydraulicing. Most experienced alluvial miners are acquainted with such instances, and many have been the schemes and many the failures associated with these conditions.

Recourse has generally been had to steam-driven pumps for the purpose of elevating the water from dam or river at a lower level and to provide the necessary velocity from the "giant nozzle" for breaking down the gravel.

The failures under this method may be attributed, apart from insufficiency of gold or water supply, to an under-estimate of the power required to elevate the large supply of water absolutely necessary. As every 100 cubic yards of gravel require 1,000 tons of water, more or less, it is evident that the power required must be a most serious consideration, and that only ground of comparatively high value will justify the initiation of such a scheme.

*Method E.*—At first blush the conditions obtaining under this head would appear to impose difficulties of too serious a nature, particularly in the case of rather poor ground, to admit of successful results. Yet strangely enough the method to be described has been, and is, successfully applied in Victoria and New South Wales to the treatment of gold and tin-bearing ground varying in depth from 12 to 60 feet, and even to 80 feet.

Table B, compiled from particulars given in "The Australian Mining Standard" of January 14, 1904, shews that certain sluicing companies in Victoria, with a capital of from £2,000 to £8,000, are working ground in abandoned alluvial diggings, and in stream beds of a value of from 3.17 to 5.8 grains of gold per cubic yard to profit on the small capital involved.

This method of hydraulic mining, frequently misnamed hydraulic dredging, may be shortly described as follows:—

The plant consists of a pontoon strongly constructed of crossed pine baulks, sheathed with pine planks, on which are placed two high-pressure tubular boilers, a compound condensing engine, one centrifugal pump for creating the artificial head and forcing the water through the giant nozzle for breaking down the gravel, and one centrifugal gravel pump for sucking up the gravel and discharging it and the accompanying water on to an elevated sluice-box, where the gold or stream tin is caught. In certain cases part of this sluice-box is erected on the pontoon, and the remaining portion, leading to the dump, is erected on trestles, but the better system is to have the whole erected on independent trestles.

The pontoon at the beginning of a cycle of operations is settled on a levelled portion of the bed-rock as near the gravel bank as practicable, the jet from the giant nozzle is directed against the gravel, which is swept along a channel prepared in the bedrock to the sump-hole close to the pontoon, from which the gravel pump sucks water and gravel, and then discharges them through 12 or 14 inch sloping pipes to the elevated sluice-box, as illustrated in Pl. XXIX., Fig. 1, which shews one of the claims of the late Hon. John Wallace, at Yackandandah, Victoria.

TABLE B.  
POWER HYDRAULIC SLUICING AT CASTLEMAINE, VICTORIA.  
From “*Australian Mining Standard*,” January 14th, 1904.

REPORT—1904.										
	Subscribed Capital. £	Acres Treated in 1903.	Depth in Feet.	Gold Yield per Acre. oz.	Cubic Yards Treated.	Yield per Cubic Yard. grs.	Wages Paid. £	Fuel Cost. £	Dividend Paid. £	Nett Profit. £
Forest Creek Hydraulic Dredg- ing Co. ... ..	7,875	5½	14½	303	135,318	5·812	2,114	809	2,812	3,305
Golden Point Dredging Co. ...	3,000	8	12	130	154,880	3·22	3,170	868	400	
Castlemaine Junction Sluicing Co. ... ..	2,000	8	14	203	180,693	5·59	3,250	945	1,700	2,350
Little Bendigo Hydraulic Sluicing Co. ... ..	2,000	4½	14	186	101,440	3·97	2,000	767		
Loddon Gold Dredging Co. ...	3,000	6	26	277	251,680	3·17	3,318	1,027	1,027	



When the gravel face gets too far from the pontoon to allow the gravel to be swept to the sump-hole, a new site is prepared for the pontoon, the paddock is flooded with a sufficient depth of water, and the pontoon is floated to its new position, the water is pumped from the paddock by the centrifugal pump, or is drained by a tail-race, the various pipes and sluice-boxes are refixed and hydraulicing is begun again.

The sluice-box is at least 80 feet long by 5 feet wide, and is provided with special riffles and perforated plates for catching the gold.

To run this plant night and day from 24 to 30 men are employed, and the working cost, of which fuel forms a large item, particularly where the depth of gravel is great, is under favourable conditions 3d. per cubic yard, but may run as high as 6d. In economy it cannot compare with simple hydraulic sluicing or even with bucket dredging, but it is superior to the latter system in permitting the bed-rock to be thoroughly cleaned up, and in being particularly applicable to ground where large boulders occur. It is, however, evident that it can only be advantageously employed in ground that is not heavily waterlogged or from which inflowing water can be readily drained.

#### DREDGING.

As the class of auriferous ground available for the simple operations of the alluvial miner or the more elaborate installations of the hydraulic miner became rarer, attention was directed to the untouched gravels lying in river beds, waterlogged valleys, and even to ground which had been already worked by hand.

The first attempt to work this class of ground by a system of dredging appears to have been made on the Clutha River, near Alexandra, in the Middle Island, New Zealand, by a man named Brown, who constructed a simple spoon-bucket dredge. Mr. W. H. Cutten, of Dunedin, thus describes it:—

\* “This spoon was simply an iron ring and ox-hide bag, attached to a long pole, with a hauling rope fastened to an iron ring and led ashore to a hand-winch. The method of working was to carry the pole, with the bucket attached, out into the river in a boat, and drop it down to the “wash” at the bottom, pressing the bucket down by means of a pole, while the whole contrivance was hauled along the bottom to the shore by the winch. The “wash” thus obtained was then cradled in an ordinary miner’s cradle.”

The next step was the fitting of spoon and winch on a punt and collecting auriferous wash on it to be cradled in the ordinary way. About the year 1870 a man named Sedeberg applied steam power to a spoon-dredge, but the operations of this and other spoon-dredges were greatly retarded, and in many cases

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\* W. H. Cutten, “Dredging as a Profitable Means of Working Alluvial Auriferous Drifts.”

rendered ineffective by the large quantities of tailings discharged into the Clutha from the sluicing claims operating on the banks.

Finally, at the instigation of an engineer named Charles McQueen, a company was formed by Dunedin and Alexandra men to construct a large elevator bucket dredge, which started work in 1882 on the Clutha River. To Charles McQueen belongs the credit of practically initiating in dredging a system of placer mining which has had a wide application in New Zealand, Australia, and America, has reached Borneo, Siberia, and South Africa, and is to be again tried in Madagascar.

Quoting again from Mr. Cutten, we find him saying, "In the year 1889 a wealthy and enterprising Chinaman, named Sew Hoy, took up a claim on the Shotover, a tributary of the Clutha River, which was known to be rich in gold in the early days. A company was formed of three hundred £10 shares, and a small steam-bucket dredge put on the claim. Although the ground had been thrice worked by hand, twice by Europeans and then by Chinamen, the dredge got so much gold that the £10 shares rose to nearly £250 each. A boom set in, and ground was taken up in all manner of places, quite regardless of its gold-bearing qualities."

Before proceeding to describe a modern bucket-dredge, it may be well to refer to the conditions under which it can work. Everyone is so familiar with harbour dredges and their mode of operation that it is necessary to correct certain pre-conceived ideas that may not unnaturally be formed regarding the scope and the effects of gold dredges.

The object of a harbour dredge is to give greater depth to channel or berth by the removal of mud, sand, and gravel, and to this end the material dredged is discharged from the buckets into a hopper in the dredge itself or into independent hoppers, and in either case the material is taken out to sea and discharged. In a gold dredge, however, the material raised at the front of the dredge is merely passed over gold-saving appliances and delivered behind the dredge into the river or valley from which it was taken; and in the case of a river, whether it carry a depth of water or be only a string of water holes, there need be no change of general conditions through the operation of dredging.

Familiarity with harbour dredges naturally engenders the idea that a considerable depth and flow of water are necessary for the operations of a gold dredge, and it is on this feature particularly that one's ideas require adjustment. Suffice it to say in this regard that wherever sufficient water exists in the gravels or can be led into the dock, or "paddock" as it is termed in dredging parlance, to float the dredge, there the operations can be carried on. (See Pl. XXXI., Fig. 1.)

Dredging in New Zealand was for many years confined to river beds, where no difficulty existed in depositing the débris

behind the dredge, but in 1894 Mr. W. H. Cutten, of Dunedin, realising the enormous possibilities existing in the gravel of wide river valleys whose surface stood high above the normal water level, designed a continuous bucket or tray elevator for stacking the tailings at the stern of the dredge. This device "caught on" at once, and widened enormously the field for dredging. Dredges working under these conditions are shown in Fig 2, Pl. XXIX., and Fig. 1, Pl. XXXI., which illustrate work in Araluen Valley, New South Wales.

Within the limits of a short paper such as this it is impossible to give anything but a general sketch of the features of a gold dredge, and it may sufficiently elucidate the subject to give the following brief description:—

The hull is built of timber, except in the rather rare cases where special conditions have led to the use of iron or steel, and in plan it is usually rectangular in shape, from 85 to 110 feet in length, 25 to 30 feet in width, while in depth it ranges from 5 to  $7\frac{1}{2}$  feet. Running longitudinally from the bow for two-thirds of the length is an open space or "well," allowing a free upward and downward movement to the bucket ladder. In swift-running rivers the square is preferable to the tapered bow, as less "jawing" results, but the underside of the bow is sprung or bevelled upwards. For working in "paddocks" the bow is rounded at the corners to facilitate working in the confined space.

The bucket ladder is strongly constructed of steel, and is suspended at the upper end by trunnions resting on the gear framework, and at the lower end by a steel wire rope attached through heavy multiplying blocks hung on a gantry at the bow straddling the well, to a drum of the winch, and can thus be raised or lowered at will.

The buckets, constructed of steel, with heavy spring steel lips, usually form the alternate links of a continuous chain, but in America they sometimes constitute each link. Their capacity in modern dredges ranges from 4 to 7 cubic feet, and they move at a speed of 10 to 12 per minute. The buckets deliver their load on a drop shoot, and from this point there are two methods of treating the gravel.

In the simpler method the auriferous gravel is delivered into a gold-saving sluice-box of the ordinary type, but provided with special riffles, and is finally discharged as far as possible behind the dredge. It is evident that this class of dredge can only be used in rivers or flats where the gravel is low-lying and comparatively shallow. (See Fig. 1, Pl. XXX., illustrating Tulloch and Hughan's Dredge, Araluen River, New South Wales.)

In the second method the gravel passes into an inclined revolving cylinder or trommel, with perforations varying in diameter from  $\frac{1}{4}$  to  $\frac{3}{8}$  of an inch at the upper end to as much as 1 inch at the lower end. This trommel or screen, as it is called,

may vary in length from 12 to 30 feet, in diameter from 3 to 4½ feet, and may be single or in duplicate. (See Fig. 2, Pl. XXX.)

Placed as high within the screen as possible, and extending the full length, is a water-pipe, with rows of perforations on the under side, from which a shower of water plays on the gravel. The coarse gravel passes out at the lower end, and, when the conditions do not necessitate stacking, falls on a steel shoot, which drops it as far behind the dredge as possible, as shown in Fig. 2, Pl. XXX. The finer material and the water which have passed through the perforations in the screen fall on a series of tables generally placed athwart ships, sometimes on one side and sometimes on both sides of the screen.

The tables, whose total width corresponds to the length of the screen, constitute the only gold-saving appliance, and are divided longitudinally in 3 feet widths. They are covered with calico overlaid with coarse cocoa-nut matting, and on this again is laid wire netting or expanded metal. The upturned edges of the expanded metal form a series of riffles guarding the gold entangled in the rough fibre of the matting. The bulk of the gold is caught at the top of the tables close to the screen and on the divisions towards the top end of the screen. No mercury is used in the operation.

Where the gold is fairly coarse and shotty, this arrangement, crude as it may appear, gives surprisingly good result, but where the gold is light and flakey there is no doubt that a large percentage, possibly at times as high as 30 per cent., may be lost.

The possible occurrence of nuggets too large to pass through the perforations of the screen has exercised the minds of many dredging men, and a series of strong riffles is sometimes placed in the stone shoot leading from the screen, but as a matter of fact little gold is caught at this point.

As previously mentioned, the disposal of the débris where the surface of the ground operated on is very little above water level and the ground is not deep, is easily effected by means of shoots leading behind the stern of the dredge. But where the débris "stacks high" recourse must be had to a "tailings elevator" of one kind or another. The sloping continuous tray elevator designed by Mr. Cutten, as shown in Fig. 1, Pl. XXXI., has been in use since 1894, and has done very good work. In America rubber belt conveyors have been suggested as a substitute for the tray belt.

Another extremely ingenious appliance, invented by Mr. Peck, of New Zealand, has been applied during the last three years to several dredges. It consists of a drum, with two blades or beaters, faced with heavy manganese steel, making 240 revolutions per minute. The gravel and sand are delivered into the drum and thrown with great force to the required height behind the dredge. Tailings can by this method be piled to a height of 70 feet above water level. The first cost of

this elevator and the six horse-power driving engine is small, the wear and tear are slight, and on account of its lightness, compared with the tray elevator, it effects a great economy in the cost of the hull. The Ngapara Dredge, New Zealand, fitted with this appliance, is illustrated in Fig. 2, Pl. XXXI.

It is now possible to dredge to a depth of 50 feet below water level and to stack the tailings to a height of 70 feet above water level, at a cost, under favourable conditions, not exceeding a penny per cubic yard, facts which speak volumes for the perseverance, ingenuity, and management of New Zealand engineers, to whom is chiefly due the remarkable progress made in this industry.

The quantity of material treated by a gold dredge varies with the size of the buckets and with the freedom with which the gravel falls and fills the buckets, and may vary from 5,000 to 15,000 cubic yards per week of 144 hours.

The work is carried on night and day in eight-hour shifts, and the staff for actual manipulation consists of one dredge master, three winchmen, and three stokers, while sundry other labour is necessary for bringing fuel on board and for effecting repairs. The cost of placing a dredge in commission ranges from £5,000 to £12,000.

Passing reference only need be made to other styles of dredges, such as the Priestman grab dredge, the suction dredge, and the shovel dredge. The Priestman dredge has been proposed for gold dredging, and one is said to have been used in South America, but it does not possess features likely to commend its general adoption. Suction dredges have been proved again and again quite unsuited for the conditions common to such work, and shovel dredges working on the principle of the steam navy, which have been tried in the United States of America, do not seem to have gained favour there with the dredging public.

The processes for recovering alluvial gold just described are in no way intricate, in fact they look "as easy as falling off a log," and it may possibly be on that account that many persons who have acquired a smattering of the subject, either theoretically or practically, have frequently fallen into errors in estimating the suitability as to value and physical condition of ground they may have examined. The most common mistakes are made in over-estimating the value of the ground through careless or inefficient methods of testing, in under-estimating the difficulties arising from the physical conditions, and in the application of wrong methods and unsuitable plant.

Finally, and above all, the initiation of permanent work should only follow thorough and satisfactory investigation.

The laws and regulations relating to dredging have been as many and various as the different states to which it has been introduced. Each Australian state must needs differ in its laws from New Zealand and from one another, as in their rail-

way gauges, and the anomaly was at one time seen of New South Wales levying a tax of one pound per acre per annum for dredging areas, while Victoria levied half-a-crown. Latterly, however, New South Wales fell into line with Victoria and Queensland in this respect.

It has now become an axiom in the countries where dredging has obtained a footing to legislate for it in a spirit of liberality, and there is wisdom in this, particularly as regards prospecting areas, for dredging is an industry dependent on economy in all directions. To act otherwise is to stifle the industry.

#### EXPLANATION OF PLATES XXIX.—XXXI.

Plate XXIX. :

- Fig. 1.—Power Hydraulic Sluicing, Yackandandah, Victoria, Australia.
- Fig. 2.—Proprietary Dredge, Araluen Valley, N.S.W.

Plate XXX. :

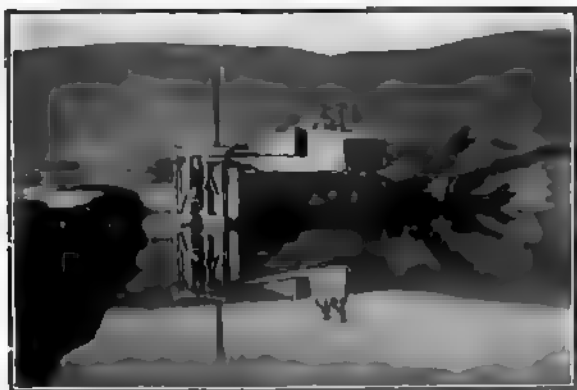
- Fig. 1.—Tulloch & Hughan's Dredge, Araluen R., N.S.W.
- Fig. 2.—Sofala Co.'s Dredge, Turon. R., N.S.W.

Plate XXXI. :

- Fig. 1.—Consolidated Co.'s Dredge, Araluen Valley, N.S.W.
- Fig. 2.—Ngapara Dredge, N.Z., fitted with Peck's Centrifugal Elevator.



**Fig. I.**



**Fig. II.**

*J. H. Ronaldson : Hydraulic Sluicing*







Fig. I.

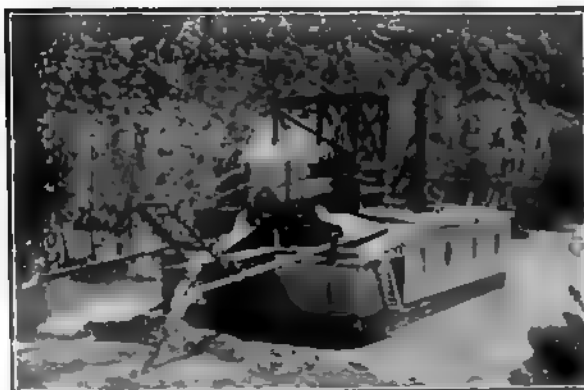
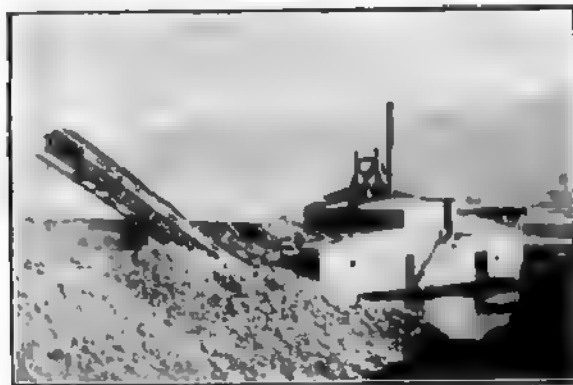


Fig. II.

*J. H. Ronaldson : Hydraulic Sluicing.*





**Fig. I.**



**Fig. II.**

*J. H. Ronaldson : Hydraulic Sluicing.*



## 26.—SOME PRACTICAL OBSERVATIONS ON FORESTRY.

By D. GOUGH MULDOON.

For the most part a knowledge of trees can best be obtained from practical experience and observation on trees themselves. There are some things, however, that can be more easily and rapidly learned from books. Firstly, we can learn best from books important and peculiar features, and, in any given class, what points specially require attention; secondly, many species foreign to particular localities must of necessity be studied from books: thirdly, there are some things in connection with trees that can be more readily learned from books than from experiment, such as how to handle, transplant, and cultivate them.

Knowledge will be gained more quickly, and will be more comprehensive and much less likely to include erroneous notions if obtained, not alone from the natural objects, but in part from the best works on the subject; so in silvicultural studies that teaching will be more valuable which leads the student to combine original investigation with the study of the literature dealing with his subject.

### LIFE PROCESSES.

Trees are living things, with vital functions and parts. They have systems of digestion, assimilation, and respiration, with specialised organs for carrying on the various processes in much the same manner as in animals.

In correspondence with most of the species comprised in the vegetable kingdom, their leaves have the power under the action of sunlight to absorb carbonic acid gas from the air, to break it up, and, with the carbon obtained and water, to form starch, returning the oxygen to the air unused. Water is absorbed directly from the soil through the roots and stems, and carries in solution such mineral compounds as the trees can readily utilise. These are drawn away to the branches, stems, and roots, there converted into living substances, and made a part of the tree tissues.

To carry up the supply of minerals from the roots to the leaves much more water is required than the tree can utilise in the formation of starch. The excess passes off as vapour through the pores of the leaves into the atmosphere, by a process of transpiration.

A tree breathes for the same purpose as an animal. It absorbs oxygen and exudes carbonic acid gas. The process is not centred in a special organ, but goes on over all parts of the leaves, branches, and roots. In the leaves the breathing goes on through the pores; in parts of the trees covered by bark it goes on through the lenticles, which latter can be recognised in the small light-coloured raised spots plainly seen on the growing branches of nearly all trees. Breathing is an entirely separate process from that previously mentioned, in which air

is absorbed by the leaves, split up into carbon dioxide and oxygen, with retention of the carbon dioxide and exhalation of the oxygen. Breathing goes on both day and night, and at all seasons of the year, though more rapidly in summer than in winter.

#### LIFE-HISTORY.

A tree has a definite life-history as an organism, with periods of growth, maturity, and decline, and characteristic development in the matter of form and size. There is a marked difference in the rate of growth of different trees, and even of the same tree at different ages. Most of the Pine family grow very slowly for the first 10 or 12 years, and much more rapid subsequently; other trees, such as the tulip tree, grow rapidly for 40 or 50 years, and then more slowly. Still others, such as the oaks, have a very regular rate of increase throughout the growing period. Great variation exists in the age at which trees become mature. While some reach maturity at the age of 50 or 60 years, many of the most valuable commercial trees only reach that stage at the age of 150 to 200 years. The redwood of California, again, is not mature before the age of 1,000 years. A tree will continue to make some growth through its maturity and decline, though during its maturity its height growth has almost ceased and its diameter growth is slow. Decline begins when the destructive forces exceed the growth forces.

Given the same climatic and soil conditions, one tree will assume one form, another a form very different. The beech will form a round, much-branched top; the red cedar, a slender tree with a central stem. The oak will reach majestic proportions; the dogwood will become nothing more than a shrub; the hickory will form heavy elastic wood, the birch that which is light and brittle. The pine will yield resin and turpentine; the oak, tannin; the maple, sugar. Thus each preserves perfectly its identity in external form and internal structure and composition.

#### REPRODUCTION.

A tree reproduces either by seeds or buds. In nature, reproduction by seed is more common, although reproduction by bud is quite as regular as by seed in some species. The tendency of the loquat to sprout from the roots and of oaks to renew growth from the stumps are examples of bud reproduction. The forester in handling wood land depends upon both methods. Such trees as reproduce only by seeds he keeps by leaving seed trees distributed over the land when the crop of timber is cut. Those that reproduce from buds renew their growth from stumps of the cut trees. Not only does bud reproduction take place when the buds are attached to the parent tree, but also when separated from it. A tree may be divided into many parts, each part becoming a new member. This

gives rise to propagation by cuttings, grafts, and buds. Many forest trees may be propagated by cuttings, and nearly all can be grafted and budded.

#### FOOD.

In harmony with all other living things, trees require food. Their food is composed of the carbonic acid obtained from the air, and the water and mineral compounds obtained from the soil. Carbon, oxygen, hydrogen, nitrogen, magnesium, calcium, iron, sulphur, phosphorus, potassium, and chlorine are called essential elements, because, with trees, as with all other plants, their presence is necessary to vigorous life. Other elements are absorbed when present in the soil in soluble form, but their absence causes the tree no loss in vigour. The elements are not absorbed separately and alone, for they rarely exist in that condition, but are blended together with one another into compounds. Thus, from water the plant obtains both hydrogen and oxygen. Potassium, nitrogen, and oxygen are often united in the form of potassium nitrate—a valuable plant food.

#### SOLUBILITY OF PLANT FOOD.

Trees are able to absorb the mineral compounds only as they are in solution in the water taken up by the roots. Many compounds of the soil which contain valuable food elements are insoluble in water, and therefore unavailable. Thus, while potassium is an essential element, it may be in such combination with aluminium, silicon, and other elements as to be insoluble and useless. Chemical changes are slowly going on in the soil by which insoluble compounds are converted into soluble compounds. Cultivation and fertilisation hasten such changes, and to achieve these is one of their chief purposes.

#### QUANTITY OF FOOD.

When the food of a tree is in available form, the greater the supply the more rapid the growth. Fertile soil has an abundance of good material, with the result that a tree situated upon it grows rapidly. Sterile soil is deficient in food materials, consequently a tree situated upon it grows slowly. The same cause, together with the conservation of moisture, explains the difference in growth between cultivated and uncultivated trees upon the same kind of soil. The cultivated tree, with its larger store of food and moisture and its protection from the competition of weeds and grass, rapidly outstrips its less fortunate neighbour.

#### ESSENTIALS TO GROWTH.

A tree can only grow when supplied with air, light, moisture, and heat.

Air is necessary because it supplies the oxygen used in the process of respiration, and holds the carbonic acid gas used in forming starch.

Light is essential that the tree may carry on its process of digestion. So sensitive is a tree that it will change its form and habit of growth to obtain the quantity it needs. In a thickly-planted group of trees the edge will bend outwards, whilst those in the interior will grow tall and slender, the growth of each hastening in the direction of greatest light. In the absence of light a tree ceases the process of digestion by which its food is prepared for use, and in a short time even loses the organs concerned in its preparation—that is, the chlorophyll bodies which give the green colour to the leaves.

The necessity of moisture is a matter of common observation. Water is one of the chief agents in the nutrition of a tree, as already mentioned, entering into its food in large quantities and serving as a carrier of food materials from the root to the leaves. With the diminution of its water supply a tree lessens its growth and sheds part or all of its leaves in its endeavour to survive. If the supply continues to decrease it finally withers and dies. Yet in their demands for water trees differ vastly. Some can thrive only with their roots in constantly saturated soil, as, for example, the Tamarack of the Northern and the Bald Cypress of the Southern States. There is every degree of variation between trees of this character and those of the desert, where the annual rainfall is limited to a few inches.

Every tree is adapted to a certain range of temperature, depending upon its power to endure heat and cold. Some, like the palms, can thrive only with a constantly high temperature, others, like most of the oaks, are adapted to alternating seasons of heat and cold; still others, as some of the birches and poplars, can endure extreme and continued cold, provided they experience a short period each year warm enough for growth. Such adaptations account for the distribution of forests over nearly the whole of the earth's surface not constantly covered by ice, and also largely for the character of the forests in different regions. Temperature and moisture principally determine forest distribution and growth. It is not uncommon to find very different growth on the north side of a mountain from that on the south side.

#### EFFECT OF CHANGE IN SURROUNDINGS.

A change in the surroundings of a tree always modifies its habit of growth. If the change is towards more favourable surroundings, the result is seen in increased vigour, and rate of growth and size; if towards unfavourable surroundings, the reverse will be true. The stately Eucalyptus tree of Gippsland is reduced to a shrub in the Mallee. The reason for this is that it is out of its range of adaptation. Many other species which grow tall and vase-like in Victoria are, in the semi-arid plains of Queensland, low and spreading, like an apple-tree. Nor is the form the only variable character. On the western trees the leaves are fewer in number, smaller, thicker, and much



rougher than on the Gippsland trees. In other parts of the tree there are differences of the same kind, though they are not so noticeable as those in the form and foliage. These variations have resulted from the difference in soil and climatic conditions to which the tree has been subjected. The difference in form between two trees of the same kind in different localities has come about through gradual divergence of characteristics. To a certain degree changes of this kind can be brought about in practice. When a gradual change is made in the surroundings of a tree a corresponding change takes place in the tree itself. Thus, if the stock of the eastern Eucalyptus be slowly moved west through many generations, it will gradually change in form and other characteristics, and become like the western tree; and it is obvious that this change is necessary to enable it to live under the new conditions. Sudden changes in the surroundings of a tree frequently cause its death, because it cannot quickly change itself to meet the requirements of its new conditions. The Gippsland Red Gum moved at once to the semi-arid Mallee is likely to die, because it is not adapted to the conditions of soil, light, heat, and moisture of that region. In many of the swamps and marshy parts of Australia where once the Eucalyptus of the moisture-loving kind used to flourish, the draining of the swamps and marshes, and consequent drying out of the soil, has caused the death of the trees. Suddenness and intensity of change often accounts for the failure of trees to thrive when moved away from the regions to which they were adapted. This is also why eastern trees so often die when moved to the west, and why nursery stock grown in a given vicinity can be more safely planted than that grown in a distant region. It is a practical matter, and should be generally understood.

#### PRACTICAL FORESTRY IN THE TRANSVAAL.

The advent of the mining industry on the Rand emphasised the scarcity of timber for mining purposes in the neighbourhood and the disadvantages of not having a good supply, and inquiries were made as to the most practical and economical means of procuring timber. Seeing that the mining companies, in some instances, held large areas of fertile land, many of them adopted the excellent idea of planting out plantations of Eucalyptus trees, knowing, as many of them did, the excellence of this timber for their requirements. Their efforts were, however, of very little avail, owing to the unfortunate circumstance of having planted the wrong varieties. Nor was this the only mistake, as it was found that the soil and climatic conditions were so favourable for the production of trees that an error was made in planting them too closely together, thereby causing them to grow skywards too quickly, and become lank. This has either been the result of want of knowledge of the characteristics of the tree planted or of the favourable conditions for the growth of the trees in the Transvaal.

The principal species of tree planted is the Blue Gum. For mining purposes this timber is practically useless, and is always rejected in Australia in favour of the more durable hardwoods, such as Yellow Box, Red Gum, Iron Bark, etc., which preference for hardwood is reflected in the respective prices, Blue Gum being obtainable at 5s. per 100 ft. running measure, and Red Gum at 14s. for the same quantity. Blue Gum is useless for any underground work, such as fencing posts, railway sleepers, ground plates, etc., and it is never used for bridge piles, beams, piers, or telegraph poles. Whilst the hard wood varieties above mentioned are all in great demand for fuel, Blue Gum is at a discount. It has not the lasting or heating powers of Box or Red Gum, and is useless for charcoal. Red Gum, on the other hand, is unsurpassed for charcoal-making, and is preferred by many smiths to the best coal, on account of its sparkless nature. It also takes the place of coke in drying hops.

All of the hardwoods of Australia grow well in the Transvaal. In some plantations I have seen Red Gum, Stringy Bark, Jarrah, White Gum, and many other varieties, but in very few instances have they had any higher value set on them than the Blue Gum, through the want of knowledge on the part of the caretaker in charge. In one plantation I saw stringy bark trees, 60 ft. high, only 12 years old, and in the same plantation there is a clump of beautiful Jarrah. The trees are the picture of vigour, and are sufficient proof that this valuable timber tree can be grown in the Transvaal. Nor were they the only ones of value. In the same plantation are to be seen many Red Gum trees doing well, notwithstanding the unfavourable conditions under which they are planted, being only spaced 6 ft. by 4 ft., when they should have been 15 ft. by 15 ft., with a row of Black Wood between.

In the Botanical Gardens, Durban, I saw a fine specimen of Iron Bark. This valuable wood is used throughout New Zealand for girders and heavy work. The girders are shipped from New South Wales to New Zealand under the supervision of an expert, who passes all timber before shipment.

The possibility of the Transvaal becoming a great yielder of hardwoods is illustrated by the fact that a large number of the Australian hardwood trees are growing well at the present time.

Below is appended a list of the trees that will grow well in the Transvaal and become valuable as timber producers:—

<i>Ordinary Names.</i>	<i>Aboriginal.</i>
Teak.	
Beech.	Binna Burra.
Cedar.	Woodgee.
Cudgery.	Cudgery.
Boligum or She Beech.	

<i>Ordinary Names.</i>	<i>Aboriginal.</i>
Blue Fig (makes excellent sculls).	
Rosewood.	Kinga Kinga.
Red Bean.	Bogum.
Brush Iron Bark.	
Red Gum.	
Stringey Bark.	
Yellow Box.	
Black Wood.	

All the above are valuable timber varieties. Some of them are exported to Germany to make piano tops, etc.

The less useful trees are the following:—Ironwood or Booyong, Redcarwood, Sour Apple, Soap Box, Snap Short, Pencil Cedar, Black Apple, Corduroy, Tripe, Sassafras, Marble Wood, Maiden's Blush, Satin Wood, Lime, Lemon Tree, White Rosewood, Lilly Pilly, Tameron Toothache Tree (Yill Yill)—said to cure toothache—Coolaman, Gray Plum, and Water Gum.

#### FORESTRY DEPARTMENT.

In order to inculcate the right knowledge and enthusiasm regarding trees in the Transvaal, it seems to the writer that a Forestry Department is required—to be under the control of a practical man—which will distribute trees gratis to all applicants. The Government would have the first call on the forestry department for trees, to be followed in order by municipalities and associations, farmers, and land-holders. A careful record of all trees distributed should be kept. Packing and delivering to railway should be done free of charge, the consignee being charged only with the carriage. The department to have free access to all lands planted, and to be furnished with a statement as to the condition of the trees which have been distributed gratis. This practice is carried out in South Australia and Victoria by the respective Governments, and enormous numbers of trees are distributed annually. These trees are nearly all sugar gum (*Eucalyptus croynocoly*), and for a dry region this is one of the most suitable among timber Eucalyptus. This species was selected and introduced into Algeria as far back as 1851. It can withstand protracted heat and cold, and is certainly deserving primary consideration for quick wood culture. It is deplorable that planters in the Transvaal have been almost universally unacquainted with the special qualities of their timber in reference to technical applications.

#### HOW THE RAILWAY DEPARTMENT CAN ASSIST FORESTRY.

If the railway department of the Transvaal could be induced to plant trees from Volksrust to Germiston, along the railway, Eucalyptus on the southern side, and Acacia on the northern, the benefit and saving in fuel would be great. Only persons experienced in locomotive work know how difficult it is to maintain steam whilst flying across that bleak portion of

country. Nor is the shelter to the engine the only good that would result from the planting of trees, as they would be developing into potentially valuable sleepers; beams for bridges; gate posts; and timber for making and repairing trucks. A further beneficial result of the suggested planting along the railway would accrue by reason of the drainage of moisture from the road-bed, which would obviate sinking, and economise in upkeep.

The Railway Department could further advance the object of forestry and horticulture by giving liberal prizes to station-masters in each district, as an inducement towards ornamental planting of the platforms and surrounding lands. In awarding the prizes the judge should be an expert horticulturist, who should take into consideration the skill of propagation, and suitability of species. This is important in its bearing upon future growth, with respect to obscuring signals, etc.

#### FREE DISTRIBUTION OF TREES BY GOVERNMENT.

The Government could, by distributing trees gratis, induce land-owners to plant hardwood trees to act as break-winds. If the land-owners by a free distribution were induced to plant, they would quickly realise their value and plant annually, either trees which they have propagated or purchased. I would advise farmers to plant in all cases hardwoods. Stringy barks are very easy to grow, and their uses are legion, but care must be taken not to plant too closely—say, 20 ft. by 20 ft. spacing, or, if the ground is limited, 15 ft. by 15 ft. will be sufficient. Red Cedar or Black wood could with advantage be planted between the rows. The Blue Fig of New South Wales is well worth a trial in this Colony, and is a handsome and useful tree.

#### TEACHING FORESTRY IN STATE SCHOOLS.

State school-teachers should be induced to encourage the children to plant trees, and if a day were set apart for that purpose annually, and the scholars were each to plant a tree, it would encourage them to plant also at their homes, thus cultivating a liking for horticulture, which would gradually grow and be of use, not only to them, but to the country in which they settle hereafter, whether it be the Transvaal or elsewhere. It would, in my opinion, be money well spent if the Directors of Education had an expert to visit the schools and give lectures on forestry and horticulture, and its practical uses. The introduction of this scheme would create in a short time an appreciable and beneficial change in the surroundings of the Transvaal homes.

#### ASSOCIATIONS FOR BEAUTIFYING TOWNS.

In many of the cities of the Australian Colonies associations are formed for the purpose of beautifying their towns or cities. These associations work in harmony with municipalities, and take over waste and sightless land, and plant it with shrubs and flowers. Almost the entire work is done by members

of the associations. Members who have gardens and spare plants present them to the association in furtherance of its general objects.

I may here state that the principal members of these associations are ladies, who receive very valuable assistance from the curators and landscape gardeners of the towns. Many of the nurserymen also take a keen interest in these associations.

#### FORESTRY IN OTHER LANDS

The Transvaal is not alone in being badly supplied with timber; many of the older countries are in the same plight. Greece, that was once a thickly timbered country, sold her forests for ship-building, and as no provision was made to re-plant trees, much of the aforesaid forest is now a treeless waste.

In China proclamations are posted in certain districts offering to decorate with the order of the Yellow Button any person planting 10,000 trees.

The United States have an extensive forestry department, and have been very successful with Eucalyptus timber, and have also planted many thousands of acres with Salt Bush, a most excellent fodder shrub, which would do well in the Transvaal.

Germany has large plantations of Eucalyptus. Many useful discoveries have been made in the laboratories of the forestry department in connection with the preservation of timber. Their forestry department furnishes an example that might with advantage be followed here. In German New Guinea particular assistance is granted in forestry. The timber plantations have consequently proved successful beyond all expectation, and are being greatly extended. In the Royal Botanical Gardens, Berlin, there are many glass-houses devoted exclusively to the propagation of commercial trees and plants, that yield rubber, cocoa, coffee, dye, farina, fibre, gum, gutta-percha, nuts, pulse, resin, spice, tea, timber, tubers, etc., and these, when sufficiently grown, are shipped to the German colonial possessions, most suited to their development. When plants yielding new, or comparatively new, commercial products are sent abroad, planters are fully advised as to the cultural requirement to ensure success, and the methods to be adopted in order to place the produce in the best possible condition on the market. What is being done by Germany in this particular is certainly of permanent benefit to her colonial possessions.

Norway stands alone in being the only country that is increasing her forests. For every tree that is felled it is compulsory to plant one, by which method the area under timber is found gradually to increase.

#### TREES INDIGENOUS TO THE COLONY.

Quite a quantity of useful work awaits the forestry department of the Transvaal, in naming and classifying the timber indigenous to the colony, of which there is quite a wealth. In the northern portion of the colony I have had the opportunity

of handling and studying some of it, and find that there are numbers of species well worth cultivating, both for their durability and their power to resist the white ant. During the recent war much of this timber was cut down, but it is a pleasing feature to note that they are nearly all propagating from the stumps. I believe from my knowledge of the timber in the Waterberg district that it would form an excellent paving material for streets, and commend it to the attention of the City Fathers. Seeing that a Fencing Act is about to become law, I would recommend a trial of some of the thorn bush of this district for "live" fencing. I am of opinion that the result would be excellent.

The difference in the climate between the Waterberg district and the Rand is very marked, the climate of the former being quite sub-tropical. For this reason I would suggest the planting of Eucalyptus from northern New South Wales and southern Queensland, known as Brush box (*Eucalyptus Tristinia Conferta*). It attains a height of 150 ft., with a diameter of 5 ft.; its timber is tough, strong, and durable. If cut at the wrong time it warps and twists, but when felled at the proper time and moderately seasoned it makes a valuable wood, useful for paving blocks, planking, flooring boards, and railway sleepers. It has been satisfactorily proved that it is obnoxious to the white ant. It can be propagated only from seed.

#### STREET TREES.

A very noticeable feature in the towns of the Transvaal is the absence of street trees, which is invariably remarked by persons coming from older countries. Street trees require to be treated artificially, and, that being the case, natural laws are in many instances completely upset, with the result that the object sought for in theory often ends disastrously in practice. A great deal may be overcome, if we would acquaint ourselves more with the various characteristics peculiar to each type of tree, observing also what effect each branch or branches have in building up a symmetrically formed tree. Many shrubs, for instance, may, by careful attention, be assisted to take on more of the tree form, and again, many plants designed by nature as trees are often made to grow as shrubs owing to the skill of the operator. Climatic influences will also assist in causing trees to take on a different character, also certain prevailing winds may have to be taken into consideration. One or all of these factors may completely upset the object we have in view, if not carefully considered and adaptations made accordingly. Nature will do her part if the intelligent observer will assist.

Another matter in relation to trees, which is often lost sight of, is the form and growth that are necessary during the early stages. These are often quite different from the growth made when the trees are matured. I am confident that a little intelligent experimenting will show what species are most suitable as

street trees. The majority of those now planted in our towns and which are expected some day to make admirable street trees, will, with few exceptions, prove disappointing, these remarks especially applying to the *Acacia* and *Eucalyptus*.

#### FORESTRY BILL.

A step which, in my opinion, it is important the Government should take is the framing of a Forestry Bill, dealing with Crown Lands. This Bill should be drafted on lines calculated to extend State forests, such as the appointment of rangers, the issuing of licences to saw-millers and timber-getters, and the reserving of certain portions for propagation and future use. Assuming that the Government were to frame a Bill, which subsequently became law, the Minister of Lands would require to have all forest lands classified, so as to determine which land is suitable to be permanently set aside as State forests, and which for temporary reserve, until the timber thereon has been cut. Any land set aside as State forest should not be available for sale in any circumstances, and leases should be granted for grazing purposes only. The Governor should be given wide powers for temporary reservation or revocation of reservations.

Licenses to obtain timber, bark, stone, or other products from State forests, timber reserves, or Crown lands, should be granted by the Minister, subject to fees, and under prescribed conditions.

Certain trees and certain lands could be exempted from the operation of the licenses.

Any State forest land should be thrown open for operations under mineral or metal mining license. Restrictions should be imposed in respect of ring-barking.

Penalties to be fixed and powers of seizure conferred on police.



## 27.—DURATION AND AREA OF HEAVY RAINFALLS.

By D. C. LEITCH, M.Inst.C.E.

To have some means of estimating, even approximately, the duration and extent of heavy rainfalls is important from many points of view. It is true that the discharge of flood water from a given area is what, for practical purposes, it is usually necessary to determine, but an essential factor in estimating this, especially where the area is small, is the character of the rainfall.

The duration and extent of a heavy shower, as well as the rate at which it travels, depend on so many fortuitous circumstances as to make it out of the question to attempt to do more than formulate roughly approximate rules. Even these, however, are often useful where nothing better is, from the nature of the case, available.

### DURATION OF HEAVY FALLS.

The records of heavy falls, as might be expected, do not show any definite relation between the rate of fall and its duration.

This relation may, however, be expressed approximately in several ways, the form  $y = \frac{a}{x + b}$ , due originally I believe to Prof. Talbot, is as good as any.  $y$  = rate of fall in inches per hour.  $x$  = duration of fall in minutes, and  $a$  and  $b$  are constants which have different values in different countries. For the British Isles  $y = \frac{146}{x + 21}$  approximately. For 499 American stations with 1 to 50 years records, Prof. Talbot gave  $y = \frac{360}{x + 30}$ . This is deduced from a very large area, and probably does not fairly represent the actual conditions in any particular district. Observations at 20 American stations in the Eastern and Southern States, mostly extending over 30 years give  $y = \frac{270}{x + 25}$ . Observations for 16 years at Washington, U.S.A., give  $y = \frac{160}{x + 20}$  for that place.

At Johannesburg, the records extend over a period of 15 years, but unfortunately the instruments in use have, at all but one station, been read as a rule only once daily, the record of duration of heavy falls is therefore very imperfect. So far as it goes, it indicates the following relation between rate and duration:  $y = \frac{290}{x + 40}$ .

It should be added that this does not cover one very remarkable fall, observed by Mr. Burt Andrews on 12th February, 1898, when 4.86 inches of rain fell in one hour at Doornfontein.



tein, and which very largely exceeded any other recorded in the Transvaal, or, so far as I am aware, elsewhere outside the tropics. To give some idea of the phenomenal nature of this fall, it may be remarked that the next heaviest fall in one hour recorded here did not exceed 2.29 inches; this occurred on the 29th February this year. The heaviest fall in one hour in the British Isles has never exceeded 1.8 inches. In the United States, outside of some rather doubtful Californian records, the heaviest fall observed in one hour has been 2.55 inches.

#### AREAS OF HEAVY FALLS.

The fall of 4.86 inches in one hour, referred to in the last paragraph, was only registered at the Doornfontein rain gauge; on the same occasion 1.1 inch fell at Joubert Park, about three-quarters of a mile away, and 1.25 inches at the reservoir, only a-quarter of a mile away. It may, of course, have been the case that the instrument at Doornfontein was on the western verge of a large area covered by this fall, but it seems more probable that the latter was confined to a small part of the southern slope of the high ground near which the Doornfontein instrument was placed.

It is, of course, likely that in most cases heavy falls have no definite limits, but gradually merge into areas of lighter rainfall. Except where such falls are due to topographical causes, as where rain clouds pass over a range of hills, it is likely that they travel for some distance before they are exhausted. It is consequently extremely difficult to obtain any direct evidence as to the probable maximum rate of fall over a given area, although for many purposes it is necessary to make some assumption as to this, in default of information regarding it.

Several well-known formulae for calculating flood discharges, such as those of McMath, Bürkli-Ziegler, and others, make the discharge per second, with the same rainfall rate, vary as a power of the area, which varies from 0.75 to 0.80. As these formulae are based on experimental data, it is likely that, at least, under the local conditions in which they were framed, they are fairly accurate; although the assumption of the same maximum rainfall rate over both large and small areas is probably erroneous. It seems more likely that over areas not exceeding a few square miles, the rate of flood discharges under the same conditions would vary very nearly as the rate of rainfall, and that the variations actually observed are due to the fact that the maximum rate of fall is much higher for small than for large areas.

Much useful information bearing on this point could be gained by comparing records of flow from drainage areas of different sizes, and under varying conditions of rainfall. So far any such data available here are very scanty. From published information it appears that the recent flood at Bloem-

fontein was calculated to be due to a rainfall of about 2½ inches over the catchment area, about 14 square miles, but this rate of fall may, of course, have extended over a larger area. The records of the heaviest falls recorded at Johannesburg do not afford much assistance, as most of the gauges have only a daily record.

Such as they are, these records are given below :—

TABLES SHEWING HEAVIEST RATES OF FALL IN INCHES PER HOUR  
RECORDED AT JOHANNESBURG SINCE OCTOBER, 1897.

Date.	Duration of fall in min.	Rate of fall in inches per hour.	Remarks.
19th Oct., 1897	15	3.2	
11th Feb., 1898	30	2.42	Only at Joubert Park. Gauges at Doornfontein and Reservoir did not record more than 0.61 in. and 0.12 in. respectively that day.
12th Feb., 1898	60	4.86	Only at Doornfontein: 1.10 in. and 1.25 in. at Joubert Park and Reservoir respectively
26th Dec., 1898	65	1.34	At Joubert Park. At Cemetery 2.57 in. fell during the day, but at Doornfontein and Reservoir only 0.53 in. and 0.82 in. respectively.
29th Feb., 1904	60	2.29	At Joubert Park. At Bellevue and Cemetery falls of 1.85 in. and 1.59 in respectively occurred.

These very fragmentary data, so far as they go, support the view that heavy falls are very limited in area, though they are far from offering anything like an adequate basis from which to infer the probable maximum rate of fall on a given area in this district. Pending the collection of further data and as a rough practical guide, it is thought that the formula

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 $y = \sqrt{A + 4}$  where  $y$  = rate of fall in inches per hour and  
 $A$  = area in acres may be taken for areas not exceeding about 100 square miles.

## 28.—SOME CONSIDERATIONS RESPECTING IRRIGATION IN THE NEW COLONIES.

By W. R. BELL, M.Inst.C.E., F.R.Met.Soc.

The practice of irrigation has been proposed among other things as a panacea for the troubles of Africa, but there is no royal road to irrigation—except in Egypt and India. In these countries the vastness of the results to be attained were of themselves sufficient to fire the minds of the men who have overcome the difficulties, climatic, financial, social, and economic, that make irrigation in these countries an achievement.

In all other countries irrigation has grown by slow and painful degrees, wresting the treasures of life bit by bit from the unwilling earth.

In the Transvaal the first question, in spite of the fact that the annual rainfall is equal or nearly so to that of countries where irrigation is little required, is, to find the water; the last, to find the market for the produce; and between these two there are many difficulties. That these difficulties only make the problem more alluring goes without saying, and that a solution of them is to be found, is predicated by the existence of the land, the water, and the people, which are necessary and are intended for one another.

Regarding the rain, it is often said that there is an abundant rainfall, but that it falls at the wrong time. That may be so—for the complainant—but it is a question whether any other arrangement would be more effective for the uses of man when we shall have learned how to use the bounty, while there is no question at all but that none of us could arrange a more beneficent time-table for the clerk of the weather.

The rain comes in summer, it is abundant in the east and north, on the high veld fairly so, and in the west and south it is deficient. Its general effect is to harden the surface of the soil, in which action both the sun and the wind contribute their powerful assistance. This effect is well known to those who, having dug, prepared, and planted their garden, find two or three days after the first heavy shower that the surface of the ground is as hard as a board.

In the next place, the characteristics of the high veld are rounded hills of wide extent, intersected with narrow valleys. Thus the gathering grounds are flat, and only the run-off from heavy rain can reach the storage areas, while the latter perforce occupy, in many cases, the arable lands of the valleys.

On the other hand, the flat gathering grounds favour percolation, especially in the rocks of the coal measures, along the escarpments of which the numerous rivers of the Eastern Transvaal spring forth.

In the sandy districts of the Western Transvaal the difficulties of flood storage are largely economic. Although the average annual rainfall is a fairly abundant one—leaving out the question as to whether the droughts of recent years point to

a change of climate—yet the recurrence of successive years of drought, followed by years of heavy rainfall, necessitates reservoirs of such size as will serve to equalise the supply over several years, a proposition that at present is hardly practicable for irrigation projects, particularly when the losses by evaporation and percolation are taken into account. And the problem is not to be solved by storage on a small scale, as the same difficulties are intensified in small reservoirs.

In the arid districts of other countries where irrigation is practised, there are generally precipitous mountainous regions of greater or less propinquity, which are regions of heavy deposition, and consequently the problem resolves itself into a question of transportation by canals, but in the Transvaal generally there are few opportunities of conveying water for any considerable distance, and the floods must be collected and stored close to the localities where the water can be utilised.

The irrigation areas are thus circumscribed and self-contained.

In the absence of detailed observations over many years, the amount of rainfall available for storage is a very difficult matter to determine. It varies, as is well known, with the physical and orographical features of the gathering ground, with the intensity and duration of the rainfall, and with the condition of the soil as respects moisture and heat.

Another question requiring determination is the amount of water necessary for raising different crops in this country, and the amount at present actually so used, also the proportion of the total annual amount which will be required at certain seasons. In this connection the science of irrigation, as a part of agriculture, must be studied, and experimental stations permanently established, to study the most profitable and economical use of water.

We require information on the above heads before we can tell how much land can be cultivated by irrigation—how many acres of gathering ground will be required for the irrigation of one acre of arable land.

For instance, supposing the rainfall to average 24 or 20 inches per annum, and that the average run-off of water amounted to 10 per cent. of this, we would have  $2\frac{1}{2}$ , or say, 2 inches of water over the whole water-shed, available for storage and use, equal to 4,646,400 cubic feet of storage water per square mile of gathering ground. If, then, 150,000 cubic feet of water—equal to about 42 inches in depth—be necessary to irrigate each acre for a year, we would have, from each square mile of gathering ground, sufficient water to irrigate in round numbers 32 acres.

This means that, supposing the amount of arable land necessary is situated where it can be commanded by irrigation supplies, we would be able (theoretically) to put five per cent. ( $5\%$ ) of the whole lands of the country under an irrigation supply.

As this supply would equal a rainfall on the ground irrigated, of 42 inches annually, in addition to the natural rainfall, it will be seen that there is a large margin for economy in the use thereof, with a consequent extension of the irrigated area.

In the Orange River Colony, again, with its wide plains and capacious river beds, the problem is different. Here the projects will be individually of greater magnitude, and the difficulty will be to find storage basins of sufficient capacity to impound the volume of water brought down in times of flood. It has been proposed to lead the flood waters from the rivers, into the natural basins or pans. This could certainly in many cases be done, but no one has yet proposed how the water is to be got out of the pans for use on the land, and the utmost that could be expected of such undertakings would be that they might augment the supplies of underground water by percolation, and, by retaining the flood waters, assist in some measure to modify the climate.

Such speculations cause us to reflect what will be the effect of the increased utilisation of water in the new colonies, upon the districts lower down, on the Vaal and Orange Rivers, and as we are always anxious to cry out before we are hurt, complaints have already been heard, that the prospective irrigation schemes in the Transvaal have affected the water supply at Kimberley!

As regards underground supplies of water, there are undoubtedly large areas containing water in the rocks, but here we must not be led away by visions of our imagination. Judging from the general structure of the country, and applying, as far as is applicable, the knowledge of facts and results obtained in the Cape Colony, where a correct view of the actual conditions has been attained, it would seem unlikely that deep artesian stores will be found, that is to say at depths over a thousand feet or so. At the moment of writing, the writer is travelling through a district where the presence of newly-built farmhouses, each with its wind engine and its patch of green cultivation in the midst of the desert mountains, attest the practical success of the Cape Water Boring Department.

Another enticing vision is that of water power. In the flatter districts of the new colonies water is too valuable, and the loss of head in water engines would entail too great length of transportation canal to command irrigable land, to allow of any great utilisation of water for power in these districts; but along the great eastern escarpment from north to south there are immense reservoirs of power, which should be strictly reserved for manufacturing industries in the future. In these regions alone does there seem to be any possibility of the Transvaal ever becoming an exporting country.

We turn here to the question of markets, without which practically no human industry can exist. And first and foremost, for many years the mining industry alone is the only agent

through which this country can be developed, and a self-supporting population settled on the soil. For mining purposes water is a paramount necessity—at any rate, at the present time—and though the want of water in places may compel the invention of other methods, yet the convenience of water as a conveying medium in the extraction of metals is so great, that it will continue to be so used at any cost less than the most exorbitant. Thus, then, vested interests hampering the use of water in mining must not be permitted, and as mining can only be practised in certain limited areas, wherever such areas be discovered there agriculture must give way to mining.

The water question is a Government question in the widest sense, in which the Government supplies and focuses the directive power, but eventually it is the people who must supply the enterprise and reap the reward, and this Association can assist in the work by taking part in the collection of sorely-needed information. They can also approach the Government with a view to disseminating widely among the public the meteorological information, the collection of which Government, through its several departments, is now organising.

We are accustomed to magnify our difficulties, each in his own walk of life, whether as exercising the sacred privilege of grumbling or as boasting of our achievements. The latter we in the Transvaal cannot do yet, for as yet we have done nothing, but to our difficulties we look with confidence as the sure road to success, and the object of this discursive paper is to invite discussion, that we may have our difficulties and our manifold advantages more clearly set forth.

## 29.—SURVEY PRACTICE IN THE TRANSVAAL.

By PHILIP B. OSBORN.

In dealing with the subject matter indicated by the title which I have selected for these notes, I should like to observe at the outset that it is more from a general standpoint than from the particularly scientific aspect that I shall review the question. That is to say, I do not propose to enter into intricate calculations or trigonometrical problems, supported by masses of figures, however interesting such a study might be, but I shall aim rather at describing the gradual growth and development of what to-day is recognised as a high standard of survey practice, from the time of the voortrekkers and the early settlers in this colony to the present date, and I shall endeavour to illustrate the salient features of what that progression is from the crude and rough methods first employed to the present systematised and scientific basis.

The unit of land measure adopted by the early settlers was 100 paces, and was taken, certainly erroneously, to be equal to 300 Cape feet; this was termed a "minute," because it was assumed that the speed of an ordinary horse was about 100 paces per minute, and accordingly, any measurement of the length of a line as applied to the mensuration of land was referred to in minutes and fractions of a minute. Of the convenience of such a ready and practical method of land measurement there can be no question, but it was not only largely inaccurate, but was the source of ever-recurring trouble in respect of boundary disputes. When the early settlers had established themselves in a new tract of country, each man, by mutual agreement, selected and beacons off a piece of ground 60 minutes square, which, according to the value of the unit of measure, included roughly 3,750 morgen; but confusion arose in consequence of the over-lapping of boundaries, for the reason that every man laid out his ground without knowing what his neighbour did, and without any real plan.

To prevent disputes and obtain an accurate written title to ground, accompanied by a sketch plan defining the boundaries, etc., the community chose three trusty men to act as a commission, called "the Inspection Commission," whose duties were to lay out the country in equal squares of the dimensions at first intended, and to deal with all questions affecting boundaries, beacons, and title.

This commission, furnished only with a pocket compass for direction, and an ordinary watch for time, divided the country off into farms, each supposed to be a square of 60 minute sides, containing an area of 3,750 morgen.

A glance at the map of the country will show with what painful inaccuracy their intention was carried out. Indeed, it is difficult to realise that the original scheme was to lay the country out into squares of more or less equal dimensions. The extraordinary figures assumed by the farms are mainly due to



the rough methods of land measuring referred to, and the deviation from squareness is largely due to the land-grabbing and beacon-shifting propensities of the voortrekkers, who, in this respect, closely resembled the early barons in the Old Country.

The system of riding off farms was maintained even to the time of ex-President Kruger, but later on an addition was made to the commission of a duly certificated government surveyor.

Landmeters, or surveyors, first made their appearance in the country in the sixties, but they had to work in a wild, inhospitable land, under exceptional difficulties, receiving, moreover, little or no remuneration for their services. It is not surprising, therefore, that they have left no particularly accurate records of their work for their successors to profit by. As an instance of the general regard in which the work of a surveyor was held, a story is told of one of the craft who, when called to book for some act of commission or omission in an earlier survey, indignantly asked the Surveyor-General, "What more do you expect for a bag of peaches?"—that being apparently all the remuneration he obtained for his services.

In the seventies further progress towards the perfection of surveying operations was made on the arrival in this colony of qualified surveyors from the Cape Colony. These men started work here under particular advantages. They had an open country, almost entirely unsurveyed, offering great facilities for good work on account of its remarkable suitability for triangulation. They also had a knowledge of the defects of the Cape system, and had a free hand to experiment in attempts to improve the application of the co-ordinate system as practised in that colony.

That system, as applied to this country, was introduced by the late Leopold Marquard, the late Samuel Melvill, the present Surveyor-General of the Cape, Mr. C. L. H. Max Jurisch, and others.

Those who have not studied the methods adopted in this country may be apt to claim that there is no difference in up-to-date practice here and other parts of the world, because the co-ordinate system is also used elsewhere, but that is an error.

Unfortunately, the objects of this paper preclude my going into details and figures in proof of that statement, but anyone interested, who cares to make the comparison, may read Mr. Leopold Marquard's "Co-ordinate Geometry applied to Land-Surveying," and the appendix to Mr. Max Jurisch's work on natural sines and co-sines, where he may study:—(1) The application of the system; (2) the reduction of all calculations to a purely mechanical process; and (3) the completeness of the checks and their use; and the result of his investigation must be to admit the advantages of our methods.

It may be noted that now, with the exception of a few who were certificated to practise in the earlier days, most of the surveyors practising in this country are university-trained men.



University training, as you all know, is beneficial over and above its ordinary scholastic equipment, in that it gives an equality of education on one particular subject, and this advantage is claimed to be very noticeable in respect of our local surveyors. Many good men may be turned out under the ordinary pupilage system, but there is invariably that lack of equality, or level, or standard of professional equipment, and the dissimilarity of methods employed, to act as a disadvantage. As a matter of fact, in nearly every such case each man appears to work out his survey in a different manner. The university-trained surveyors, using one method and one system, are more or less equal, and the public are not called upon to pass judgment on their respective qualifications. So to speak, each man is as good as his fellow, and the only difference is the ripper experience gained by age, but except for his longer experience in the field, the elder surveyor would have no advantage over the younger.

The advocacy of university training for Transvaal surveyors has found a champion in the person of Professor Hele Shaw, who, in his eloquent address, delivered at the Degree Ceremony of the Cape University, said, "The old idea that there are only four professions worthy of university recognition, viz., arts, theology, medicine, and law, has broken down."

There are new professions to be included, and one of them is surveying. Now, if a medical man had obtained his knowledge, first as an assistant to a chemist, and next by helping a duly qualified practitioner, he would not be licensed by the Government, nor be employed by the public, and there seems to be no reason—I certainly can see none—why the surveying profession should be placed on a lower level than the medical profession.

To render the title to ground secure; to indelibly sketch the whole and true extent of land owned on a diagram, and to thus make the owner's title indefeasible—surely these are important attributes of civilised life, which, if not comparable to the losing or saving of life itself, comes very near to it. There is, indeed, no valid argument against including the surveying profession as one of the learned professions, entitled to its proper sphere in a university curriculum, and recognised as on an equality with medicine, theology, or law.

Let me come now to another matter, viz., land tenure.

As affecting land tenure, there are two classes of surveys in this country:—

(1.) Original.

(2.) Sub-divisional.

In the case of original, or first surveys, the surveyor frames diagrams in triplicate, which are submitted to the Surveyor-General for examination. The diagram is examined as to the consistency of its numerical data, and is compared with existing adjoining surveys, being also scrutinised as to its accuracy in

respect to its registration of title. It is then approved by the Surveyor-General, who writes his signature against a certificate on the diagram to that effect. The next process is three months' publication in the "Government Gazette," calling for objections, if any, as regards beacons and boundary lines on the ground. Should no objections be made, the Surveyor-General writes his signature against another certificate on the diagram to the effect that the latter is confirmed. One of the copies of the diagram is filed against the titles in the Deeds Office, and is called "the original diagram." The second copy, which carries the revenue stamps, is issued to the owner with his title deeds—which are true copies of the original titles in the Registrar of Deeds' Office—while the third copy of the diagram is retained by the Surveyor-General.

In the case of the sub-divisional diagram, a similar examination is made, but the diagram is not kept at the Surveyor-General's office for inspection. Indeed, this diagram is only approved, and not confirmed. Being only a portion of the original diagram, publication and confirmation are not necessary, as the public cannot be interested in the boundaries of a portion of the property, the boundaries of which have already been published and confirmed.

But these methods only apply to isolated surveys, and not to the survey sections into which the country was divided under the Law of 1891. It is noteworthy that under this law the country was divided into sections, which were parcelled out to the different government surveyors, so that each surveyor got a section.

At the time this arrangement was made, Mr. Kruger convened a meeting of surveyors, and explained to them the nature of the law, remarking, further, that every surveyor should have an equal slice of the country. At this meeting the Surveyor-General observed that there were a few bad surveyors in the country, and it would be unwise to give such reputedly bad men a section; whereupon Mr. Kruger replied, "No, give every man a section, and those that are wicked, inspan them 'Naas achter' (next to the hind oxen) where I can reach them with the sjambok," but as results will show, there must have been very few of the "landmeters" who fell within the reach of Mr. Kruger's sjambok.

Each surveyor was compelled to make an independent triangulation over his section, and, by connecting with the surveyor's work in the adjoining section, a proper check was assured from each base, and thus a network of triangles was carried across the length and breadth of the country.

On this triangulation the surveyor based his farm surveys, all existing surveys were checked, and new ground was surveyed and brought into diagram.

All this work was done at a fixed tariff and paid for by the Government, who afterwards made the owners of the farms repay the costs of survey.

The accuracy of the work done by the land surveyor is well reflected in the subjoined statement, which shows the latitude and longitude of points on the borders as fixed:

- (1) by calculation from the known position of Pretoria, using the data of the ordinary farm surveys of the Transvaal;
- (2) by actual observations in the trigonometrical survey of the Cape Colony and Natal;
- (3) by astronomical observations made by Mr. E. H. V. Melvill.

WESTERN BORDER.

Bn 1 on Convent. line (Calcutat.)	25	38	10.84	25	34	48.20
(Bechuanaland Trig. Survey)	25	38	10.60	25	34	59.
Difference ...			0.24			10.80
T 25 on Convent. Line (Calcutat.)	26	6	49.28	25	34	0.55
(Bechuanaland Trig. Survey)	26	6	48.60	25	34	10.
Difference ...			0.68			9.45

SOUTH-EASTERN BORDER.

Noma ... (Calcutat.)	28	13	29.50	30	25	12.70
(Natal Trig. Survey)	28	13	28.56	30	25	8.81
Difference ...			0.94			3.89
V K R ... (Calcutat.)	26	57	58.97	29	54	20.07
(From Natal Trig. Survey)	26	58	0.20	29	54	30.53
Difference ...			1.23			10 46

EASTERN BORDER.

Kamshlabana ... (Calcutat.)	25	43	0.51	31	24	50.53
(Melvill's Astr. Obser.)	25	42	57.80	31	24	44.0
Difference ...			2.71			6.53
H B (Wilson's Kop) ... (Calcutat.)	25	30	51.57	31	44	11.40
(Melvill's Astr. Obser.)	25	30	47.70	31	44	4.10
Difference ..			3.87			7.30
B 60 (Mamelons Kop) (Calcutat.)	25	25	19.20	31	46	31.08
(Melvill's Astr. Obser.)	25	25	15.80	31	46	24.00
Difference ...			3.40			7.08

(For this information I am indebted to Mr. W. M. Gilfillan, Assistant Surveyor-General.)

The checks I have just shown you must be admitted to be severe upon the individual surveys of a country, but the results obtained have been very satisfactory, and reflect the highest credit on the work of the Transvaal surveyor, and the excellent co-ordinate system he uses. Under this system,

where the work is carried out as accurately and as systematically as indicated earlier in my paper, all the beacons of a property, if lost or maliciously removed, could easily be replaced by any surveyor from the recorded facts on the diagram. As a base he has available for use hundreds of beacons on the neighbouring properties.

Had time been propitious I should have liked to have taken you a little further and sketched for your entertainment some of the schemes for regulating surveys in the Transvaal, which have been, from time to time, proposed and considered. I should also have liked to touch on the more scientific principles affecting the profession to which I have the honour to belong, but this paper was hastily prepared in the interludes of leisure which the responsibilities of business have allowed me, and I could do little more than deal with the historical and popular side of the question.

### 30.—THE MINE SURVEYOR AND HIS WORK ON THE WITWATERSRAND DISTRICT.

By A. E. PAYNE.

Surveyors in the Witwatersrand District have almost throughout the history of these fields been easily classified into (1) land surveyors, and (2) mining engineers, who possess, in addition to some knowledge of surveying, that certain special knowledge of mining desirable for the proper representation of underground workings.

It is not my intention to speak of land surveyors, whose practice in South Africa has been so admirably explained before the members of this Association by my friend Mr. P. B. Osborn. But it is interesting to note in passing the admirable work in mine surveying which has been done in the past and is still being done in cases by those gentlemen whose qualifications as surveyors are of the highest.

The Land Surveyor is here generally known as a "Government" Surveyor. His certificate dated from the Cape Colony, and was received by the late Government up to 1893 as qualifying him to practice in what is now known as the Transvaal Colony, and after that date to be admitted by examination conducted on the same lines as the Cape University theory and practical. Excellent work has been done by him on these fields in the co-ordination of this district, and in certain cases he was called upon to lay out reservoirs of considerable size, and to locate machine sites to the best advantage. But he was not *prima facie* a mining man, and it was only in the year 1896 that the late Government recognised the importance of qualifying men especially for mine survey work.\*

The syllabus drawn up with this object embraced a thorough training in both theoretical and practical work. The examination consisted of the same preliminary course as laid down for Land Surveyors, who could also be admitted by examination in this country; it ensured first of all a good grounding in subjects of general education, such as 1st Teachers' Examination, embracing Bible History, Algebra, etc., and the theoretical examination in such subjects as conics, spherical trigonometry and astronomy; whilst the practical part finished the course and embraced such subjects as drawing, mining principles, test survey, and knowledge of the Dutch language, in which the whole examination was to be conducted. There is no doubt that the aim was high and a good standard of efficiency procurable. But there was considerable delay in putting the Law into force. Instructions to Surveyors were not issued until October, 1897.† A Government Mine Surveyor was at length imported from Germany, and as a sign of

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\* Kalendar—Raad van Examination, and Law No. 5, 1895, approved by Law No. 9, 1896.

† Published in Staats Courant and reproduced in English in the S.A. Mining Journal, October 30th, 1897.

his effort I will call your attention to an extract from one of the local technical journals published in May, 1898,\* in which we read—"that the Inspectors have received orders whenever they visit the mines to inspect the plans and see that they are rightly coloured, and in all respects accord with the published instructions. One or two Surveyors have already been reprimanded—indeed, we have heard something about a fine." Nothing further was done, however, and I think I am right in saying that few applied to be subjected to the theoretical examination, whilst none at all completed a test survey, and none at all were admitted as Government Mine Surveyors. Some candidates even in making application were given to understand by the then Government Mining Engineer that he preferred the responsibility to rest with the mine manager.

In reviewing the mine survey practice of the Witwatersrand, one has first to take this fact into consideration, that there was no law enforced to regulate the system of surveying throughout the mines. Each group of mines established a standard of its own, whilst Government Surveyors engaged in this work followed their own ideas. It does not follow that without Government control there can be no efficiency, but there are members of every community who will not conform to the best practice of their neighbours, and in cases where reefs are wide and underground connections can be safely effected on the reef body, as well by following the reef as by sound, then such practice can dispense with accurate work, and calls into existence the half competent individual. As a result, I fear the plan record of much valuable information, especially in prospecting work, has been lost to us through lack of representation by qualified mine surveyors. This matters little, perhaps, to the shareholder in a mining venture if he knows that a profit has been made and a portion of that profit has reached him as dividend; but it matters a lot to the mining engineer called upon to report on the future prospects of a mine if he has no careful record of the past history of that mine to review.

So, passing to the conditions of the present day, we are able to place on record that, though the workings of Governments are slow, steps are surely being taken to qualify certain men for the responsible work of mine surveying. In describing the duties which confront the surveyor, I am referring to the "Mine" Surveyor, and may have occasion to refer to alterations in the law which have brought about a change in his work.

It is the almost universal custom now to employ a resident surveyor for each mine. He may have one or more assistants, according to the size of the mine. His first duty on appointment is to acquaint himself with the boundaries of his property. Here he is at once thrown into contact with the work of a

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\* S.A. Mining Journal, May 14th, 1898

government surveyor, who has surveyed the several units of claim area, of which this mining proposition may be the sum, has recorded his surveys in diagram form and in most cases has left someone else to build the beacons.

A beacon is probably too well known to all to need description, but it is without doubt the most abused representation of a point—which should have “no parts and no magnitude.” The point may be fixed by the government surveyor or the beacon may be accepted by him and fixed; but, in either case, that mark, through no fault of the surveyor's, never seems to remain for long in the exact spot, and if there be no more than one government surveyor concerned in the survey of these units, above referred to, there will probably be small discrepancies in the total area and boundaries of the property. For the most part, however, a goldfields' survey has followed the survey of small units of claims, and the boundaries of most of the older companies have long since been fixed and referred to one common origin. Government trig. stations are scattered along the fields, and the surveyor can refer to these, whilst he is always at liberty to measure his own base line and determine anew the value of his boundary beacons. In this he is largely assisted by the government surveyor's work of fixing mynpachts, werfs, and such reserves of ground prior to the proclamation of the farm on which his property is situated. So that the surveyor on these fields is not called upon to determine his own meridian, and this one factor alone admits of a standard of surveying knowledge which is less advanced than that required of the government surveyor. By this I do not mean to imply that it is unnecessary for a mine surveyor to know how to determine his meridian, for these fields do not bound the mining area of the Colony, and it may possibly occur that the government surveyor has not got sufficiently far ahead of mining work to have established any local trig. stations. But locally we can avail ourselves of the service of mine surveyors who have not advanced to this standard of knowledge.

Having determined the value of his boundary beacons to his satisfaction, the surveyor proceeds to run a small triangulation over the property which shall serve him to locate (1) his shaft or shafts, and (2) his surface works. On a comparatively new mining venture this work does not present any great difficulty, but on the older mines evidences of such surveys are easily obliterated by the extensive use of the surface for the erection of reduction plant, quarters, offices, and more particularly, waste rock, tailings, and slimes dumps. In such cases the selection of suitable triangles is often a matter of some difficulty; a base line of any suitable length cannot be found perhaps on the property, and resort must be had to a much larger triangulation from the farm boundary than would otherwise have been necessary for locating the surface objects.



These are difficulties which call for ready resource from the surveyor and test his knowledge of mathematics. The importance of locating a shaft, upon which the subsequent connection between surface and underground workings must be correctly established in relation to the boundaries of the property, cannot be overlooked.

The nature of traverse work employed by the surveyor underground is apt to warp his appreciation of both a base-line of the correct proportions and his observation of the angles of triangles on the surface. Of course it is impossible to be dogmatic and lay down any hard and fast rule as to dimensions, because circumstances alter cases. Before proceeding further with the connection of surface and underground it would be as well to follow the surveyor's work on the surface.

From the small or secondary triangulation it is quite easy to fix the surface works. The work is done in the quickest manner by means of the tachometer, of suitable dimensions to give accurate readings in accord with the scale to which the work is to be plotted and the degree of utility to which the plan is to be placed. In practice azimuth angles are not read to seconds, distances are read in feet, and inclined distances are not reduced for moderate degrees of dip. A sketch should accompany the record of all readings, and the dimensions of buildings, etc., are made by tape, affording a rough check on the tachometer work. In plotting, the protractor and scale are the instruments required, and the size or form of the protractor will limit the accuracy of the instrumental reading required. The triangulation often accompanies such survey work, and can be carried out at the same time. The calculation precedes the plotting, and the plan is provided with a suitable net, by means of which the trig. points are accurately plotted to form a base on which the protracting is done.

In most mines construction work is going on nearly all through the life of the mine. The mechanical engineer always wants levels, and the surveyor sooner or later will be called upon for a contour survey of some sort. A contour plan enables the mechanical engineer to form a mental picture of the whole property, and to rapidly adapt any scheme of construction to its environment. Two methods are adopted (1) a series of sectional levels with the dumpy, and (2) tachometry. The former is slow, but sure, and requires little further comment if carried out to a sufficient extent to avoid much freehand work when drawing in the contours. The latter is a rapid method giving any number of points all over the property. It has the disadvantage, however, of not shewing up local depressions or irregularities of surface, which for the mechanical engineer are so important for the consideration of his excavation and foundation work. Such contouring is rather a guide to further detail as occasion should require.



Other surface work required of the surveyor is the laying out of construction work, laying down centre lines of engines, railway sidings and dam construction.

The construction work may be extended to the measurement of masonry, earthwork and excavation work, and in many cases the surveyor will be expected to know what is good masonry, concrete, and the several qualities of cement work, and also what burden of foundations various strata can bear.

Laying down engines with an instrument, especially winding engines in line with the winding sheaves, is often required as a preliminary to fixing the template. This work is in a sense a corollary to the laying out of the line of an incline shaft on the surface. The traffic about the collar of a shaft, the many platforms and stages sometimes erected over the collar, are wont to interfere with the surveyor's shaft point. The practice, therefore, of carrying out a line and one at right angles to it, so as to recover, if not the actual point, at least the line of direction of the shaft cannot be too strongly recommended.

Laying out railway sidings is practically an innovation since the war, and is work which on the average is neither extensive nor beset with any great difficulties. Bunker capacity at the boiler house fixes the terminal level, and grades of  $3\frac{1}{2}$  to 4 per cent. have been admitted for short lengths. These and other limitations, however, have been over-ridden through necessity, since most plants have been laid out prior to the obtaining of permission to put in a siding.

Too much care cannot be given to fixing the surveyor's surface points. The object of the survey is not solely to represent contours, surface works, etc., but to be able to carry on such and always keep up to date. Unfortunately, such points as must nearly be always chosen in elevated positions on dumps and reservoir banks always disappear, and though excellent trig. points, become useless as auxiliaries.

Turning now to underground work, we come into touch with the mining knowledge of the surveyor. The primary step in connecting surface with underground has already been touched upon, viz., the location of shaft point. The shaft may be vertical or inclined.

In the case of a vertical shaft the method adopted in the past of transferring the meridian below ground has been by plumbing. I will not go into the technical details of this method, the matter has been recently touched upon in the transactions of a local technical society.\* The discussion of a paper on this subject brought to light the most recent researches and justify me in declaring that we must endeavour to find a more accurate method of transferring our meridian down a deep vertical shaft than by plumb-lines. Air currents have been

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\* Institute of Mine Surveyors, Paper by K. Sartorius, pub. S.A. Mines, 22nd August, 1903.

proved to cause important convergences and divergences in the plumbs at the foot of the shaft. The result is to cause an error in verticality of the plumb-line, and an error in the orientation of our base-line down below. The effect of such errors transmitted through several hundreds of feet of driving to connect with a similar drift from another shaft is appreciable, and can easily exceed the error allowed by regulation. To overcome such difficulty there are two possible alternatives. Firstly, to work back from a permissible error in the underground connection required to the orientation of the base. Assuming the error from the true position of the latter to be due to air currents, we can estimate a force the horizontal component of which will cause this displacement. From this we have the velocity of air current and by direct measurement of ventilation in our shaft can tell to what extent we must impede this ventilation for the purpose of our plumbing so as to keep within these limits. This is not a method which I can recommend, because in the first place we have not reached the great depths which I am anticipating, and secondly, because in practice one is not at liberty, as a rule, to spend much time over such an operation in a shaft, nor do I anticipate that one will be in a position to reduce the velocity of the air current to that required. And yet I cannot lay out any more satisfactory suggestion in coming to my second method of overcoming the difficulty. This is to return to the use of a nadir instrument and by a direct observation survey in a line at the foot of the shaft. Experiments in this direction have been recently conducted locally, but have, I understand, not met with the fullest success. We have here to encounter chiefly the difficulties of distinct vision at great depths. It is an inherent factor in the construction of a telescope that magnifying power and a distinct image over considerable intervals of space and the atmospheric conditions encountered in shafts necessitate an objective of a long focal length and of some size. Such a requirement does not come within the scope of the mining theodolite as at present constructed, and it remains to be seen whether experience will demand the construction of a special instrument for this purpose.

In the case of an inclined shaft, we have to establish our connection with the underground workings by means of a traverse. A traverse means simply the measurement of an angle between the direction of one line and another from the point of intersection of the two lines. To fix the lines their lengths are measured, and both angular and linear measurements referred to one common origin and meridian by co-ordinate geometry. You will recognise the details of backsight and foresight from a given station, and it will not be necessary for me to elaborate the points in connection with the centring of the instrument and location of bench-marks, which are important details well explained in text-books. But it is advisable to call attention to the apparently simple object of measuring this angle. I have

not so far made any reference to methods of using a surveying instrument, nor have I spoken of the instruments themselves. The mining theodolite is so bound up with the history of surveying that it would form a big treatise in itself to trace its growth and development. In fact a discussion raised in the American Inst. of Mining Engineers\* extended over a period of several years, and drew contributions from all parts of the world. In this district there are many types of instruments in use of English, German, and American make, and, almost universally, transit theodolites, sometimes combined with the tacheometer. The use of such an instrument is part and parcel of the theory of its design, and for the adjustments, repetition of angles and elimination of instrumental and personal errors of observation, I must again avoid encroaching upon the text-books. In mining work, however, there are points which are not always elaborated in text-books. It is not only necessary to check the measurement of an angle, but in addition to the elimination of the errors, I have already referred to, it is necessary to devise a method of reading that angle and recording the reading by some mechanical self-checking process.

The traverse is further extended to the fixing of relative levels of all benchmarks. This may be done in the one operation of fixing the azimuth of the new station by means of the vertical circle attached to the instrument and certain measurement of plumb-lines used, or it may be carried out independently by the dumpy level and levelling staff. Vertical angles may be read and checked by a similar self-checking process. The surveyor has to bear in mind the advisability of always being up to date with his work, and I think that these two processes should be both employed, the latter as a check on the former.

Whilst conducting a traverse along the level, the surveyor has to note the position of his station points in the drive, and to refer the sides of the drive, by off-setting or sketching to his traverse line. Faults, dykes, and dislocations of all kinds have to be fixed before proceeding and sketched in the field-book for future reference. Development work precedes stoping, so that box-holes for the stope plan will be measured in later.

Until recently it was not compulsory for the surveyor to have to represent anything more in plan than the actual drifting and stoping of the mine. That is to say, the Government did not require of him more than the representation in plan of any hole in the ground. Instructions were drawn up so as to illustrate the difference between one hole and another, but there was no call for representation of where the ore body was being exploited and where not. It is due to the present Government, who, after several consultations with the mine surveyors themselves, with the consulting engineers and with the mine man-

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Transactions American Institute of Mining Engineers, Vols. XXVII. and XXXI.

agers, decided to call for information on the plan as to the nature and extent of the reefs worked. It was only natural that the surveyor with his mining knowledge was always expected by his manager to be conversant with this important information, but he was never called upon to shew it in plan, and there was, therefore, no means of passing on this knowledge to his successor. Now, however, by a simple process of representation in colours, he is able to shew just where the reef is and just what reef it is. Minor details such as dip are further added, and the whole is now a picture of how the work of exploration is being conducted. The surveyor is called upon to show separately the work of development and the work of stoping. The representation of the stopes occupies much of his time. He must be prepared to satisfy contractors with his measurements, and he must follow up the work done by day's pay, whether by machine or hand labour. At certain fixed intervals, which may be quarterly or monthly, he is expected to be able to give a return of the total tons extracted over a certain area at a certain thickness. From his careful determination of these factors depends the estimate of the future life of the mine. He may in cases be called upon to keep the cost sheets of work done on contract, and to sign a statement of money due to contractors at a price fixed by his manager. In development work it is expected that he will guide the management in the following of reef, and in the search after it when faults and dislocations of all sorts are encountered. He will, of course, have to lay out and carry through all connections in the course of development. He will furnish the information for the return of ore reserves.

In office work he must be a quick draughtsman, neatness and uniformity of work are very advisable, but should never be sacrificed for the sake of accuracy. In calculation work there is one golden rule that all calculations made must be checked by some independent method. It sounds laborious to have to check the conversion, say, of Cape feet into English feet by turning English feet back into Cape feet, but it is the only sound principle. Surface triangles are best calculated in accordance with the practice of government surveyors of the Colony,\* affording a mechanical as well as actual check on the one point at the apex. Traverses are tackled by taking angles from the field-book in such a manner that the sum of the angles observed at any one station are adjusted to 360 degrees. These are referred to the angle of direction or bearing of backsight in such manner that an angle measured in what is often called the right-hand way or left-hand way does not need to worry the surveyor, since the angle of direction of his foresight will come out to a direction checked by another 180 degrees from it. Latitudes and departures are calculated by any two of the following methods:—Logarithmic tables, traverse tables, natural sines and cosines

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\* *Vide* Tables of Natural Sines and Cosines by C. L. H. Max Jurisch.

and the calculating machine. The addition of the co-ordinate values of a station to the calculated latitudes and departures is done twice to determine the value of the new point. There is a possible source of error in extracting the angles from a field-book, and to eliminate such an error there is much to be said for following the traverse by an independent check in using the prismatic compass. Any marked difference in the magnetic declination would be at once observed. The surveyor is often using his compass in determining the strike of any fault or in bringing the face of a drift roughly up to date; so that he will in the ordinary course of work be brought constantly in touch with a check on his direction referred to the true meridian.

The surveyor may be called upon to keep a plan record of all values as disclosed in the mine. If he has control of the sampling, his knowledge of geology is further exercised, and the assay results of samples are compiled by him in suitable form according to requirements. When the sampling is conducted independently of his office, he is not infrequently required to record on an assay plan information supplied him from the assay office.

It is obvious now, if we reflect upon the many points which I have endeavoured to enumerate, without, I hope, going too greatly into detail, that we have here a species of knowledge which we can class as professional. The Government is on the eve of granting certificates to mine surveyors, and in a sense they will be creating a distinct profession. Such a profession is, I think, worthy of consideration. In the past we have seen the mine surveyor filling such a position on a mine largely with a view to perfecting his knowledge of mining engineering, and not the accuracy of his surveying methods. He was, for a man with a technical training, a not too highly paid official of the mine, filling a temporary position preliminary to that of a mine captain's work or even manager's. But now there is a hope of change of a more encouraging nature. Such accurate observation as is now required of him, such a standard as will be given him by the Government will surely create a feeling amongst the directors of this mining industry that we can better make use of this species of knowledge the surveyor is acquiring, than by allowing him to move about from one step to another in the profession of mining; that it will pay us to recognise the profession of a mine surveyor. We can couple with his duties the control of sampling and assay work, about which I have said little in my previous remarks, and thus make of him a valuator of considerable usefulness, a technical adviser on the mine, untrammelled by the consideration of business requirements in running that mine.

There are seven causes of probable error, due to alignment, inclination, comparisons with standards, readings of index, personal errors, uncertainty of temperature, and adopted rate of expansion.

In the measurement of the base on the ordnance survey of Ireland in 1847, General Colby's "compensating bars" were used. This apparatus consists of two bars, one of iron and the other of brass, placed parallel to each other  $1\frac{1}{4}$  inches apart, rivetted together at their centres, it having been ascertained that they expanded and contracted in their transition from cold to heat, and the reverse, in the proportion of three to five. At the extremities of these bars are fixed tongues of iron, with minute dots of platinum so situated on these tongues that at different temperatures they remain at a constant distance. The rods had to be supported throughout in troughs and the measurement made by visual and not actual contact, powerful microscopes being used for the purpose.

The distance measured in a day was, on the average, 250 feet. In the Indian survey, where the same apparatus was used, the speed of the measurement was greater, amounting to one mile in five days.

An appliance invented by Professor Jaderin, of Sweden, and which is gaining the confidence of geodesists, renders the measurement of a base line more easy and more rapid. This is the use of nickel-steel wires of one-sixteenth inch thick, with small graduated scales at the ends. The co-efficient of expansion of nickel-steel being very low and consistent, there is less chance of error due to the uncertainty of knowing the exact temperature of the wires.

This appliance was used by the Russian-Swedish expedition which went to Spitzbergen in 1899 and carried out the measurement of an arc of meridian, from South Cape 76 deg. 30 min. latitude north, to Rosso 80 deg. 50 min. latitude north, the wires used being kept at a given constant tension by the use of two dynamometers. Special tripods were arranged along the base-line, and the exact interval between marks on two tripod heads was measured. The readings were taken four times, and a base of 6,500 yards measured in four days, with a probable error of 1 in 400,000. The triangulation was completed towards the end of 1901.

In 1902 the coast and geodetic survey of the United States had in hand the completion of two systems of triangulation, which will form the main framework or control for all surveys in the States. Nine primary base lines have been measured, and will control the lengths on 1,100 miles of the 98th meridian triangulation. The base-lines were measured before any triangulation was started. The bases, ranging from about 6,000 yards to 13,000 yards in length, with an aggregate of 43 miles, were measured in six months, by a party of ten persons, of whom three were experienced surveyors, the average probable error



being stated as 1 in 1,200,000 (one million, two hundred thousand). The cost, including labour, standardising the apparatus, and transport, was about £52 (fifty-two pounds) per mile.

Five sets of apparatus were used, there being two 100 metre steel tapes, two 50 metre steel tapes, and the Eimbeck Duplex Bar apparatus. All five sets were used on each base, a thousand yards being measured with the five, and the remaining sections twice. From these measurements it was shown that by using steel tapes about as accurate results are secured as by using duplex metal bars, whilst the tape measurement is nearly three times as rapid. The tapes used were of thin steel, about a quarter of an inch broad. In order to secure even tension of the tapes a special apparatus is used. It consists of a lever hinged by a universal joint to a platform on which the operator stands. The lever is made of steel tubing, with a handle; the tube has a screw thread, on which a wheel-nut plays freely. This nut gives a vertical motion to a gimbal-jointed support, to which a spring balance is attached. The spring balance has a breaking link inserted between it and the tape, so that the link parts whenever too great a tension is applied; this is to prevent overstraining of the tape by accident.

The first arc of meridian measured in the Southern Hemisphere was done by the Abbé de Lacaille in 1752, near Cape Town. It was thus a matter of great scientific interest to determine whether the form of the earth in the Southern Hemisphere is similar to that in the Northern Hemisphere. This arc was nearly  $1\frac{1}{4}$  degrees in length.

The length of a degree of latitude (34 deg. S.), derived by Lacaille from this survey, was for a long time a subject of perplexity to theoretical investigators of the figure of the earth, as the resulting length was much greater than it could be if the form of the earth in the Southern Hemisphere were the same as in the Northern Hemisphere, and Lacaille's reputation for accuracy ensured respect for his work.

The discrepancy remained unexplained until Sir Thomas Maclear, then Her Majesty's Astronomer at the Cape, undertook the verification and extension of Lacaille's arc.

A new base-line was measured, nearly on the same site as Lacaille's, 8.1 miles in length. This was started in 1840, and the field work and observations completed in 1848. Maclear's arc has an astronomical amplitude of 4 deg. 37 min. in latitude, and proves, within a very narrow limit, that the form of the earth in the Southern Hemisphere is similar to that in the Northern Hemisphere.

The astronomical amplitude of the arc was found to be very nearly the same as that of the arc of the Northern Hemisphere.

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partly for the purpose of forming reference points to correct the then very inaccurate and defective state of the charts of the coast, and partly to afford means of better connecting the detached property surveys, through that portion of the Colony.

When, in 1862, the work was completed, the survey party embarked at Algoa Bay en route for England on board the ill-fated steamer "Waldensian," which struck upon the rocks off Struys Point, and became a total wreck, the instruments, drawings, and original observation books, sheets with full abstracts, calculation books of every kind, all complete in every respect, were lost.

Fortunately, copies of "Abstracts of Angles" had been supplied to the Admiralty Surveyor engaged on the coast survey, and other "Abstracts of Angles" to the Surveyor-General, and from these and other information supplied to other persons an account of the work was compiled by Captain Bailey, and printed in a report to the Cape Parliament in 1863.

To Sir David Gill, who was appointed as Her Majesty's Astronomer at the Cape in 1879, is due the great progress made in the geodetic survey of South Africa.

To Sir David Gill I must apologise for the free use I have made of his report on the Geodetic Survey of South Africa, made in 1895, and printed in the Cape Colony blue book of 1896. To this report, and also that of Colonel Morris, who executed the survey under the direction of Sir David Gill, and which is printed in the same blue book, I would refer anyone who is anxious to study the question of geodetic surveying, for in it there is to be found a complete account of all the operations.

The geodetic survey reported on extends from the north of Natal through Griqualand East to Port Elizabeth, from Port Elizabeth to Caledon and Cape Town, Port Elizabeth to Kimberley, Hanover to Calvinia, Cape Town to Calvinia, and a tie from Fraserburg to Oudtshoorn. The work was executed during the years 1883 to 1892.

Through Sir David Gill's instrumentality, a geodetic survey has been carried out, extending along the 30th meridian, from the south of Bulawayo to the Zambesi.

Colonel Morris is at present carrying out a geodetic survey in this colony.

Before measuring the base lines in connection with the Natal and Cape Colony surveys, the standard bar of the Cape Colony was sent to France to be tested, and thoroughly investigated. This work was, most kindly, voluntarily undertaken by the International Bureau of Weights and Measures at Breteuil, near Paris.

This standard bar was used by Sir Thomas Maclear, and is a rectangular iron bar 64.5 millimetres ( $2\frac{1}{2}$  inches) deep, by 38 millimetres ( $1\frac{1}{2}$  inches) broad. For a distance of about two inches from its extremities, it is cut down to half its height, exposing two plane rectangular surfaces coincident with its neu-



tables on their tops, to which plates of zinc are nailed. The portion of the forward end graduation of the wire or narrow tape is marked on the plates as the work progresses, by means of a sharp bradawl held against the edge of a try-square aligned against the edge of the plate, the rear-end graduation being brought in coincidence with these marks.

At each end of a base-line permanent marks are left, which can be referred to again if necessary.

The altitude of the base-line above sea-level has to be determined, for in all geodetic work it is necessary to have some base to which to refer, and that of the mean sea-level has been taken to be the most appropriate.

During the actual measurement of the base-line, the inclines of the different portions are taken, or in the case of using wires, the levels of the tops of the tripods, and the length of the base altered accordingly.

The necessity of then reducing the length of the base to sea-level for geodetic purposes is very apparent, when we consider the degree of accuracy aimed at, and also the great correction required.

Considering the earth as a sphere with a radius of about four thousand miles, a base of 4,000 yards, measured at an altitude of one mile, 5,280 feet (being somewhat less than the elevation of Johannesburg) above the sea, would, when radially projected on to the sea, be 3,999 yards, or in other words would have to be adjusted to the extent of 1 in 4,000.

Few bases have ever been measured solely for the determination of the value of an arc of the meridian, or of a parallel of longitude, but have formed at the same time the foundation of the survey of a country, consequently the stations used in carrying out the geodetic survey are generally constructed of some durable material, and also have marks that can be recovered, buried below them in the ground. Stations having thus been constructed to form a chain, or chains, of triangulations, the next operation consists in observing the angles of the triangles.

The theodolite used for this purpose must rest on a solid foundation, and when it is necessary, as is sometimes the case, that a scaffold has to be erected to support the instrument, then another has to be erected outside this to carry the observer, and these two must not in any way touch.

The instrument is adjusted at every station, and numerous readings of the various stations taken, in order to get rid of any errors of graduation, and so secure the angular values with the least degree of probable error.

Owing to the fact that the axis of rotation of the theodolite coincides with the normal to the earth's surface, no correction is required on account of its height above the sea, and as the angles measured between distant points are those contained be-

tween the vertical planes passing through the axis of the instrument and those points, the angles measured are those of a spherical triangle.

Naturally the instruments used vary in size and pattern.

The graduations are read by means of micrometers, where great accuracy is required, or by the usual microscopes. Astronomical observations are taken at such stations as are required, the direction of the meridian or true north is determined, and the azimuths of the stations noted. Further observations are also taken for latitude and longitude, to determine the actual position of these points on the earth's surface.

The actual work of observing requires a considerable amount of patience.

Owing to climatic disturbances, it sometimes happens that an observer may have to remain for days or even weeks to obtain a sight to some station he is particularly anxious to observe. It sometimes happens, too, that a station of importance has been struck by lightning, and has to be rebuilt before the necessary observations can be taken. Throughout all operations, constant watch has to be kept, that no cause of error may pass undetected. With regard to the observations of the angles, it is well to divide the time taken in making these, so as to extend over some days, or in any case that a number of observations may be taken in the morning, and a like number in the afternoon; this is to get rid of errors of lateral refraction, which at times is considerable. It is of importance to have a clear and distinct object to which to observe. That used in the Rhodesian survey was very clear and inexpensive. Two discs about two feet in diameter were attached at right angles to each other to a short piece of gas-pipe or iron rod, and this in turn fitted into a gas-pipe of larger diameter. The larger gas-pipe, having been erected perpendicularly over a mark on the surface of the ground, was made permanent by means of masonry built in the form of a cone.

All the field work having been finished, the next work is carried out in the office: this is the calculation of the triangulation.

Inevitable errors of observation, inseparable from all measurements, introduce a great difficulty into the calculations of the sides of the triangles.

Starting from a given base, in order to get a required distance (that is, the distance between any two points), it may generally be obtained in different ways, or by a different set of triangles. The results will certainly not be the same. Experience of the computer will assist him to decide on the most trustworthy result.

The angles observed being those forming the angles of a spherical triangle, it is possible to find out the sum of the errors of the observed angles. In a plane triangle, the sum of the

three angles should be equal to 180 deg., but that of a spherical triangle, somewhat greater. As the area of a spherical triangle depends upon the excess of the sum of the angles over 180 deg., so, by knowing the area, the amount of the spherical excess is obtainable. The area of a spherical triangle as generally used, being almost the same as that of a plane triangle of the same length of sides, the excess is easily arrived at. In a triangle of 75.8 square miles area, which is equal to an equilateral triangle with sides about 13 miles in length, the spherical excess is only one second, thus the excess in seconds in any triangle would be its area multiplied by .01317.

In correcting the angles of a triangle it is necessary to be guided by the weight of the determination of each angle. When a series of direct and independent observations is made under similar circumstances of any measurable magnitude, such as an angle, the weight of the result is equal to half the square of the number of observations, divided by the sum of the squares of the differences of the individual measures from the mean of all.

Let  $E$  be the error,  $H, K, L$ , be the weights of the three angles, and let  $X, Y, Z$  be the corrections to apply.

We know that  $X$  plus  $Y$  plus  $Z$  plus  $E = 0$ , and the most probable values are those which make  $HX^2$  plus  $KY^2$  plus  $LZ^2$  a minimum

Here we get a simple problem, the result of which is  $HX = KY = LZ$ , which shows that the error has to be divided into three parts, which shall be proportional to the reciprocals of the weights of the corresponding angles.

Suppose the weights equal, then we subtract one-third of the error from each.

The calculating of the triangulation can thus be made by treating the triangles as spherical triangles. It may also be done by considering the earth as a spheroid, which makes the calculations more difficult, or in accordance with Legendre's Theorem, which is the simplest.

Legendre's Theorem is:—

"If from each of the angles of a spherical triangle, the sides of which are small in comparison with the radius, one-third of the spherical excess be deducted, the sides of the angles thus diminished will be proportional to the lengths of the opposite sides, so that the triangle may be computed as a plane triangle."

By this means the spherical triangles which present themselves in geodesy are computed with very nearly the same ease as plane triangles.

The angles of the triangulation being adjusted, the next process is to calculate the latitudes and longitudes of all stations from one point. The calculated latitudes and longitudes and azimuths which are designated geodetic latitudes, etc., are not to be confounded with the observed or astronomical lati-

tudes, etc., for these last are subject to somewhat large errors. Besides the adjustment of the angles of each separate triangle, a further adjustment of the angles has to be made in treating a portion of this triangulation as a whole. This leads to the solution of a number of equations of a more or less intricate nature.

The last operation in connection with a geodetic survey is the report, in which the results are given, and the deductions made therefrom by the geodesist.

## 32.—FIRE PROTECTION ON THE MINES.

By G. H. THURSTON.

It is the purpose of this paper to deal with the precautions mining companies on the Rand should take to protect themselves from loss by fire, and with this object in view the subject will be treated under three headings—viz., Fire Prevention, Fire Appliances, and Organisation.

### FIRE PREVENTION.

It is doubtful if the present general design of surface plants on mines could be modified to any extent, and the buildings separated sufficiently to avoid the spread of fire without sacrificing economy of operation or increasing constructional costs. The particular method of grouping the buildings and the materials of which they are constructed are determined by considerations of cost rather than by the danger of their destruction from fire, and, as a consequence, almost the whole of our existing plants have been constructed throughout with timber, which has received no preparation of any kind to protect it from fire.

The use of steel construction wherever possible would considerably reduce the risk of loss from this cause. Its adoption no doubt depends somewhat on first cost, but when durability, reduction in risk of fire, and consequent stoppage of the work, are taken into consideration, the advantage of a saving in first cost becomes less. This is especially applicable to heavy structures, where the cost of steel construction enters into close competition with that of wood. There are structures on a mine, however, which do not permit of steel construction throughout. In these the floors and other portions are built of wood, which, in case of fire, would be completely destroyed, and no doubt do considerable damage to the rest of the building.

Numerous preservatives and fire-proof paints have been introduced of late years for the purpose of making wood fireproof, many of which when tested failed to establish the merits which their inventors claimed. There are, however, methods, principally chemical, by which timber may be rendered less inflammable. Zinc chloride, for instance, has a great affinity for water, and has a tendency to keep wood damp in the driest climate. Experiments have demonstrated that timber containing sufficient of the chloride for its preservation cannot be ignited until exposed for a long period to a high temperature. The Ferrell\* system of preserving timber and rendering it fireproof is one in which sulphate of aluminium is the principal chemical substance. Samples of wood treated by this process resisted the flame of a Bunsen burner for a period of eight hours.

Many fires would have been prevented by the exercise of more care on the part of workmen, who cannot be too frequently cautioned in this matter. Lighted matches and tobacco sparks have often been the cause of outbreaks of fire. A curious case

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\* The inventor of this process is Mr. J. M. Ferrell of Philadelphia, U.S.A.

of fire known to the writer was caused by a workman using a rod of hot iron for the purpose of enlarging holes in Karri timber. The man left work at the usual time in the evening without exercising sufficient care to see that no fire remained in any of the holes, which was evidently not the case, as on the workmen entering the building on the following morning they were amazed to find the place in flames. Fortunately the fire had not obtained a great hold, and was easily extinguished.

Electric wires, unless properly installed, are a source of danger, not only on account of the liability of fire from short circuits, but, in the case of high tension current, there is also danger to the fireman from electric shock. High tension circuits should be led from the generating plant direct to a transformer station, from which the low tension current can be conveniently distributed. This station should be built of brick and placed in a suitable spot, and at a distance from other structures.

The spontaneous ignition of waste saturated with oil has been the cause of many fires. Of the oils, linseed is the worst offender, cotton-seed, lard, sperm, and neatsfoot oils are also dangerous, while mineral oils having a flash-point below 300 deg. Fahr. should be discarded. All oily waste should be removed every day and consumed in a boiler furnace or other suitable place. Sawdust impregnated with oil is just as liable to ignite as waste, and is deserving of the same precaution.

Regular oiling of machinery is a very necessary precaution against fire. If bearings get hot through the friction of the parts, due to lack of oil, there is danger of the wood-work in their near neighbourhood becoming ignited.

The following information, taken from Mr. C. H. J. Woodbury's work on "The Fire Protection of Mills," will constitute a fitting conclusion to this part of the subject, and show the diverse causes to which mill fires are attributable, and emphasises the need for constant care. Out of a list of 575 fires, 178 owed their origin to sparks, 136 to friction, 121 to spontaneous combustion, 49 to lighting apparatus, 40 to matches, 10 to lightning, the remaining 41 to various causes, amongst which were 17 known or suspected cases of incendiarism.

#### • FIRE APPLIANCES.

Owing to the variety of fire appliances offered for sale, considerable judgment is required in selecting a suitable equipment. Some mining companies have already expended considerable sums in order that means may be at hand to suppress any outbreak of fire. This is a step in the right direction, but had such expenditure been made under the advice of an expert fire authority there is little doubt that their properties would have been better protected. Want of uniformity in fittings, faulty arrangement of pipes and hydrants, poor quality of hose, and obsolete pumping machinery were to be found in many

services. The writer has known both screw and bayonet couplings to be installed in the same service, hydrants located on the inside of buildings, the fire pump made to do duty as a boiler feed, and the fire hose and fittings in great demand for washing out boilers and for similar purposes. For this they are no doubt convenient, but the hose as a fire appliance is certainly not thereby enhanced in value.

Before installing a fire service the supply of water is the first consideration. Fortunately almost every mining company has a supply of water on hand for milling purposes, which can be used in case of fire. To insure that it shall be available for this purpose, a pipe connection should be made between the mill reservoir and the fire pump. This connection should have ample area, and contain as few fittings as possible. The number of valves especially should be reduced to a minimum with a view to avoiding delay in the event of any of their number being closed when a fire occurs. Amongst these fittings there should be a large strainer for the purpose of preventing chips or other obstructions entering the pump. In the case of the reservoir being at an elevation above that of the mains, a by-pass fitted with a non-return valve should be installed between the suction and delivery pipes. A supply of water at a low pressure could thus be obtained in case of emergency. A reliable relief valve should also be fitted on the delivery side of the pump, in order to guard against accident in the event of the pump starting before the hydrants are open.

The pump, which should be of a reliable make and specially designed for fire purposes, should be placed in such a position that the water will flow into it, to secure its immediate operation when wanted. A good type of pump to select is one known as "The Underwriter Fire Pump." This pump is of the horizontal duplex pattern, and specially designed to the specifications of the fire insurance companies. It has large water passages and valve areas, and a special feature in the pump is that it is rust proof and will start instantly after standing unused for a long period. In some existing fire services it is the practice to make use of the boiler feed pumps, or a pump whose chief recommendation is its cheapness; in other cases a pump rescued from the scrap pile is made to do duty, and at the same time satisfy the insurance company. These pumps are frequently placed in the engine or boiler room of the main power plant, which is a practice to be avoided, as should a fire occur in these buildings the pumps would be rendered useless. The fire pump should be housed in a special building, constructed throughout of steel and iron, and situated at such a distance from other buildings that it would be isolated should a fire occur. A good situation would be at a distance of about 200 feet from one of the boiler plants, in which case steam may be carried to the pump through properly covered piping, thus facilitating the starting of the pump. In addition to this con-



nection with the boiler plant, a quick steam-raising fire-engine boiler should be installed in the fire pump building, which would be available in case of fire in the boiler room.

The delivery service, which comprises the piping connecting the various hydrants with the fire pump, should receive considerable attention. The main should be of such area that the velocity of the water will not exceed 9 feet per second under normal conditions. In an emergency this speed may be increased 30 per cent. In any case the mains leading to the hydrants should not be less than four inches in diameter, as water on mines usually carries lime and other impurities in suspension, which in time are deposited in sufficient quantity to seriously reduce the area of the pipe. Mains should be kept clear of buildings as far as possible. In the case of hydrants a distance of 40 feet should be observed, and these should be covered with straw enclosed in a canvas cover. If not protected in this manner there is a danger of the water left in the stand-pipe freezing in winter, thus rendering the hydrant useless. The writer has known as many as five valves burst in one night in this country owing to severe frost. Compounds, carpenters' shops, smelting houses, and other places which are most subject to fire should have hydrants placed in the most convenient position. These particular hydrants must have the hose coupled and always ready for immediate action.

In selecting fire-hose the purchaser will find several qualities of both canvas and rubber-lined hose in the market, the latter, however, being only used on rare occasions. Leather hose for fire purposes is out of date. A first-class canvas hose that will fill all requirements should be hand woven, free from irregularities in weaving, and capable of standing 200 lbs. per square inch pressure. It should also be able to stand the shock due to being dropped from a height of five feet when under a pressure of 100 lbs. per square inch. All hose must be tested to 25 per cent. above full working pressure every six months to insure it being in first-class condition when wanted. After having been used, hose should be washed, carefully drained, and dried on a suitable rack provided for this purpose, then stored in the hose cart, placed in the fire station in a convenient position, which is dry, and where there is a good circulation of air. The hose attached to the hydrants for emergency use should be hung on a peg in a hose box placed above the hydrant, and coiled in such a manner that by taking hold of the branch and walking away from the box the hose will not become kinked.

Of the many different connections on the market there are but two distinct types, viz., the instantaneous and the screw. The former, when used with a reasonable amount of care, is very effective. The modern spring coupling is a great improvement on the old form of bayonet coupling, and is every bit as reliable as the screw coupling, and has the advantage of being much quicker in operation.



Branches are usually made of copper, and are from 20 in. to 30 in. long. A length of about 24 in. is found very convenient for general inside and outside work.

The size and shape of the nozzle are details to which special attention should be given. Careful experiments made in the United States by Mr. John R. Freeman to determine the most efficient form of nozzle demonstrated that the co-efficient of discharge of nozzles of the same general form when tested under similar conditions gave results which were identical within the practical limits of measurement. The difference between the cone nozzle and the ring nozzle is more apparent. In the test mentioned, the co-efficient for the cone was .988, and for the ring .736. Another form of nozzle claimed by some to be specially adapted for fighting fire inside a building is known as the "Ball Nozzle." This peculiar device consists of a bell-shaped or flaring-mouth nozzle, with a ball placed loosely in the mouth. Upon water issuing the ball steadfastly adheres to the nozzle and divides the stream into a fan-shaped spray. The position of the nozzle makes no difference. If turned towards the ground the result will be found to be the same. Variations of pressure, amounting from a pound to hundreds of pounds, will fail to dislodge the ball, and it is only when the water is turned off that it follows the law of gravity and falls to the ground. This nozzle when used inside a burning building surrounds the fireman with a sheet of water, driving the smoke before him, and at the same time extinguishing the flame.

The size of the nozzle depends on the conditions under which it is used. A one-inch nozzle will give the best results when the fire is confined within narrow limits and only one hose is at work, but when the fire has spread and three or four streams are necessary, three-quarter inch nozzles may be the best to use. Should the fire, on the other hand, occur in a high building or headgear, it is possible that half inch nozzles will be required. To provide against any contingency that may arise, three or four nozzles of various sizes should be carried in the hose cart. All nozzles should be made with a hexagon boss for the purpose of unscrewing them from the branch by means of a wrench. All hose and fittings with the exception of those attached to the hydrants should be stored in a central position, and in addition to those already mentioned should comprise the following:—

- One fireman's respirator.

- One ladder cart, containing four ladders of a length to suit the buildings on the mine.

- Two hose carts, marked No. 1 and No. 2, each containing:
  - 500 feet hose, in 50 ft. lengths.

- 3 branches, each fitted with one-inch nozzles.

- 4 nozzles,  $1\frac{1}{8}$  in.,  $\frac{7}{8}$  in.,  $\frac{3}{4}$  in., and  $\frac{1}{2}$  in.

- 1 branch, fitted with a smoke-driving nozzle.

- 2 wrecking axes.

- 2 saws.
- 1 crowbar.
- 2 canvas buckets.
- 2 50 ft. lines.
- 2 30 ft. lines.
- 2 20 ft. lines.
- 2 10 ft. lines.
- 2 pairs rubber gloves.
- 2 pairs rubber boots.
- 2 torches.
- 2 lamps.
- 2 monkey wrenches.

The hose cart should be a light, substantial vehicle, the body consisting of a box with three compartments, one for hose, one for the larger appliances, and one for the smaller. This type of hose cart is superior to hose reels, and more suitable for mine work.

In addition to the above, chemical fire extinguishers should be distributed through the various buildings, as they are of value for suppressing a fire during the early stages.

Of late years the automatic sprinkler has met with considerable support from the fire insurance companies. This device, if properly installed and tested regularly, is an excellent safeguard against fire. One of the best features of the system is the automatic fire alarm, which calls attention to a fire having started.

The writer considers that the alarm call is the most important detail in connection with the fire service, for naturally fires are easier to extinguish before they have attained any magnitude than afterwards. No matter how well a brigade is organised, or how good the appliances are, much depends upon the celerity of the alarm, on which hinges the time of the arrival of the brigade.

A mine fire alarm system should consist of alarm boxes containing a bell push. These boxes should be situated in close proximity to the various buildings. They should be made conspicuous in the day by the words "Fire Alarm" being plainly painted on the box, at night their position should be indicated by a red light. From each of the boxes a separate wire should communicate with a bell in the engine or boiler room where the whistle or hooter is installed, and they should also be connected by means of independent wires with an annunciator placed in the fire station. Upon hearing the alarm bell ring the attendant will blow the whistle until he receives a signal from the fire station notifying him that the brigade is out. For this purpose a bell push should be fixed in the station and connected to a bell close to the whistle.

In the case of mines which have a private telephone service, this could be made with a small outlay to serve also as a fire alarm.

## ORGANISATION.

The organisation and training of a mine fire brigade are matters requiring considerable thought and tact. It is out of the question for mining companies to retain the services of a large staff of permanent firemen, therefore it is incumbent on them to form a volunteer brigade among their employees, to whom sufficient inducement should be offered to encourage them to attain such proficiency in the use of fire appliances that any outbreak of fire on the mine may be overcome. It is evidently the duty of the general manager of the mine to initiate an organisation of this kind, and maintain discipline. He should also receive the hearty support of the mine staff, and to make the brigade of real value their united efforts should be exerted to infuse *esprit de corps* amongst the members.

The work in connection with fire fighting should be taken seriously. The members of the brigade should be drilled regularly, and above all it must be understood by all employees that they are under as much obligation to respond promptly to an alarm of fire as they are to attend to the duties for which they are engaged.

To accomplish the best results it will be necessary to employ at least one permanent fireman, who should rank in the brigade as an inspector. This man would take the place of the watchman whom most companies employ at present.

On large mines, or a group of mines, it may be necessary to employ more than one man for this purpose, in which case they should rank as chief inspector, first assistant, second assistant, etc. The work of the inspector, in addition to his duties as watchman, would be to test the fire alarm daily and inspect the various appliances to see that they are not used by unauthorised persons; also to report daily in a book on the condition of the fire service. This book should be kept in the office of the resident engineer, who should be made responsible for the upkeep of the service.

The officials of the brigade should consist of the following members of the mine staff:—

Chief of Brigade: General Manager.

Assistant Chief: Resident Engineer.

Lieutenants: Compound Manager,

Chief Electrician,

Foreman Fitter,

Foreman Carpenter.

The firemen should consist of men drawn from the office staff and general surface employees, and the number will vary from fifteen to thirty, according to the size of the mine.

The members of the brigade should be provided with a serviceable plain blue uniform and black helmet. For the purpose of distinguishing the officers during a fire, the colour of their helmets should be white.

In order that the men may become proficient in their duty a fire drill must take place once a week, and in addition the alarm should be sounded occasionally during the night. The men should receive remuneration for all drills they attend. The drill of a mine brigade will differ somewhat from that of a brigade organised for the purpose of suppressing fires in a city. One reason for this is that many of the buildings on a mine contain machinery which is in constant operation; this may, in case of fire, become a source of danger to those who are not conversant with it. In the event of a fire occurring in a building, machinery in motion therein should be at once stopped, and the electric current cut off. Wires carrying high tension current are especially dangerous. A case known to the writer in which a workman narrowly escaped being electrocuted was as follows:—A fire broke out in a transformer station built of galvanized iron, the high tension wires of which carried a current of 3,300 volts. The outbreak was discovered by the workman, who attached the fire hose to the hydrant in order to play water on the fire. Fortunately for the man, the Resident Engineer arrived on the scene just in time to avert a catastrophe.

The exact method of organisation and nature of the drill on each mine will no doubt vary, depending somewhat on the arrangement of plant and the status of the various members of the staff. As a general method of procedure, to be modified to suit local conditions, the writer would suggest the following arrangement:—

On hearing the alarm bell ring the engine-driver on shift is to blow the whistle until signalled from the fire station to stop; at the same time arrangements are to be made to start the fire pump. On hearing the whistle the following members of the brigade are to assemble at the pump station in order to operate the pump:

Lieutenant (foreman fitter).

Two firemen (two engine-drivers).

At the same time a lieutenant and one fireman (i.e., chief electrician and a linesman), should proceed to the transformer station or switch board in order to shut off the current from the burning building. Those assembling at the fire station should consist of Chief of Brigade, Assistant Chief, two lieutenants, and the remainder of the firemen. All orders must be given by the Chief of the brigade, and in his absence by the Assistant Chief. Should the latter also be absent, the foreman carpenter is no doubt the most competent to take charge of affairs.

Method and coolness are required in dealing with fires, and such qualities can only be acquired through training and good discipline.

To comply with the conditions advocated in this article, extra expenditure will be incurred by mining companies, which expenditure must be justified either by a reduction in the insur-

ance rates or increased protection against losses not covered by the insurance. As an example, take the case of a mine with a 200-stamp plant. The company will pay insurance amounting to about £725 per annum, which protects them from loss by fire, but not from loss of profit due to stoppage of the plant. This, in the case of a mill being destroyed, would amount to considerably more than the erected cost of this particular portion of the plant which cannot be insured for more than its value.

The cost per annum of maintaining a fire department based on an equipment costing £2,000 more than is generally expended now on fire services and on a brigade consisting of five officers and 25 men, will amount to £570 (this amount includes interest and depreciation on the £2,000).

It is evident that as insurance companies are willing to take risks at rates varying from 0.16 per cent. to 0.3 per cent. under existing conditions, these rates should be reduced if an up-to-date system of fire protection was introduced, and moreover should a fire occur, the chances are it would be suppressed before much damage had resulted, and reduce the risks of loss from stoppage.

In addition to these two advantages, companies might also be justified in reducing the total amount of insurance, for with the improved service, some of the buildings, e.g., general offices, quarters, and many structures in connection with cyanide plants, may either be insured for a lower figure or left out altogether.

In conclusion, the writer is of opinion that although it would be necessary to pay more for the purpose of maintaining a more efficient fire service, it is an outlay that is justified, as the companies would be much better protected against losses not generally recoverable by insurance.

### 33.—THE USE OF PRODUCER GAS-DRIVEN ENGINES ON MINING PLANTS.

By A. C. WHITTOME.

In the following paper the author does not propose to consider the merits and deficiencies of any of the many types of gas-producers and gas-engines on the market. His purpose is to discuss the broad principle as to whether the gas-engine, driven by producer gas, is suitable for extensive use on the Witwatersrand gold mines.

In discussing the question, it is therefore not essential to complicate the main point at issue by the introduction of details which are more or less familiar to all of us, and the historical side will only be lightly touched upon, in order to show how far the modern development of the gas motor has tended to make it such a formidable prospective competitor of the steam-engine on these fields.

The following table shows roughly the progress of the gas-engine from earliest times up to the introduction of the Mond producer:—

	A.D.
1. First Gunpowder Engine, by Hautefeuille ... ..	1678
2. First Gas Motor, built by Barber ... ..	1791
3. First Gas Engine, by Street ... ..	1794
4. Flame Ignition, first proposed by Street ... ..	1794
5. Electric Ignition, first proposed by Lebon ... ..	1799
6. First to propose compressing the charge—Barnett ...	1838
7. First practical Gas-Producer, proposed by Thomas and Laurent... ..	1841
8. Tube Ignition, first used by Drake ... ..	1843
9. First mechanically successful Gas-Engine, built by Lenoir ... ..	1860
10. First Proposer of Four-cycle Engine, Beau de Rochas	1862
11. First commercially successful Gas-Engine, built by Otto and Langen ... ..	1867
12. Otto Four-cycle Engine patented ... ..	1876
13. Dowson Producer first built ... ..	1878
14. Scavenger Process first used by Beck ... ..	1887
15. Mond Producer introduced ... ..	1894

This table does not show the wonderful improvements made by different manufacturers from time to time. It only indicates when various devices or principles were first adopted, though, in many cases, they were dropped, to be again taken up at a later date.

Bryan Donkin, in his excellent work on "Gas, Oil, and Air Engines" (to which the author is indebted for many details), claims that the origin of all internal combustion engines should be traced back to the builder of the first cannon. Unquestionably in the first internal combustion motors constructed—apart from cannon—the combustion or explosion of gunpowder was utilised to create a vacuum, so that by means of atmospheric

pressure a piston was forced downwards in a cylinder, or water was raised in an early type of pulsometer.

It is equally certain that none of these early attempts at internal combustion engines—between the years 1678 and 1710—were commercially successful. It is worthy of notice, however, that amongst the first attempts to construct motors having cylinders and pistons were these gunpowder engines.

It will be seen that no man can claim to have originated the Gas-Engine. After the first crude attempts in the end of the seventeenth century, about 100 years elapsed before any progress was made, when Barber in 1791 constructed the first Gas-Motor, a type of gas-turbine. From this period onwards, experiments have been almost continuously recorded. The first mechanically successful gas-engine was built to Lenoir's designs in 1860, but the consumption of gas was as high as 106 cubic feet per brake-horse-power hour, giving a thermal efficiency of from 3.5 to 4 per cent.

The real commercial history of the gas-engine dates from 1867, when the Otto and Langen Atmospheric Gas-Engine was first put on the market. This type, though successful, had not a very long life, and in the year 1876 Otto took out his patent for the Otto Four-cycle Engine, and for the next fourteen years (the duration of the patent) this engine was practically the only one in use.

There were others built, but none of them were very serious competitors. From the year 1877 to 1897, no less than 63,000 Otto Engines were built in the various manufacturing countries of the world. There are no figures upon record to show what were the total numbers of engines of other types built, but the above should be sufficient to show the enormous development of the gas-engine.

About the time that the Otto Four-cycle Engine was designed, the Dowson Gas-Producer was also put on the market, and the advance of producer and gas-engine may almost be said to have been step by step. The Dowson Producer made it feasible to use gas-engines of larger units than were possible when using lighting gas, owing to the much higher cost of the latter fuel per horse-power hour. The Dowson type of generator can only utilise either coke or anthracite coal as fuel, so that its use is restricted to those localities in which these are procurable at a sufficiently low rate.

In 1893 Dr. Mond successfully started the first producer plant which bears his name. The Mond Producer, using bituminous slack as fuel, opened up a fresh sphere for gas-engines. Apart from the fact that it uses bituminous coal—practically the only fuel obtainable here—it is far more efficient than the Dowson type of producer.

The best recorded heat efficiency of the latter type is 67 per cent., whilst efficiencies of over 80 per cent. are regularly



obtained with Mond generators, i.e., 80 per cent. of the heat value of the fuel used is retained in the gas produced. Common bituminous slack will produce from 150,000 to 160,000 cubic feet of gas per ton of fuel, whilst about  $2\frac{1}{2}$  tons of steam per ton of coal are needed in the process.

Types of gas producers somewhat on the same principle as the Mond are continuously being patented and developed. We may reckon that there will soon be as many designs offered for sale as there are types or designs of steam-boilers at the present time. This will all tend towards advancement, as, with so many experimenters at work, knowledge will be rapidly gained.

In considering gas-engines, one must lift one's self out of the grooves so deeply scored in engineering work by every-day steam-engine practice. Indeed, to grasp to the full extent the new conditions raised by gas-engines, it is necessary to put on one side nearly all that one has learnt regarding steam-engines, and make a fresh start.

The ordinary practice in steam engineering is to allow an ample margin of power above what is needed, when an engine is first installed. The author knows of one case where a steam-engine is installed to do the following work:—

Minimum load ... ..	350 I.H.P.
Normal load ... ..	500 I.H.P.
Maximum load ... ..	700 I.H.P.

The engine is installed for an eventual 700 I.H.P. Its present load varies from a maximum of about 500 I.L.P. to a minimum of 350 I.H.P. The steam consumption at the various loads cannot be accurately given, but an ordinary guarantee for such an engine, running under ordinary Rand conditions, would be:—

LOAD.	Lbs. of Steam per I.H.P. Hour.
350 I.H.P. (half load) ... ..	20
500 I.H.P. (five-sevenths load) ... ..	17.5
700 I.H.P. (maximum load) ... ..	16

or an increase of 25 per cent. between full load and half load.

On a gas-engine there would most probably be an increase of 70 to 100 per cent. in the fuel consumption at half-load over full-load. To obtain the best working conditions for a gas-engine, it must be run steadily at as near the maximum load as possible, and at one constant speed. It cannot be reversed in the ready manner possible with a steam engine, and it is comparatively less easy to start up. Finally, it cannot be started against full-load in the manner necessary with a hoisting engine. Therefore the work to which gas-engines can be directly applied is in some respects restricted.

Taking the ordinary work of the Rand, the following schedule will show the types of work to which gas-engines can be applied, and those for which they are not suited:—



## DRIVES SUITED FOR GAS-ENGINES.

Batteries  
 Tailings Wheels  
 Pumps  
 Locomotives  
 Mechanical Haulages  
 Machine Tools  
 Electric Generators  
 Slimes Plants.

## DRIVES PARTIALLY SUITED FOR GAS-ENGINES.

Air Compressors  
 Rock Crushers.

## DRIVE NOT SUITED FOR GAS-ENGINES.

Hauling Engines.

Under favourable conditions the working cost of a gas-driven plant would be far lower than that of a steam-driven one. To start with, the gas engine has a heat efficiency for higher than that of a steam-engine, and the heat is cheaper, i.e., lower priced fuel can be used. Instead of centralising all the engines in one engine-house, and transmitting power electrically to distant spots, gas-engines can be installed where best suited for their work, and the gas distributed to them from one central producer plant. In this manner, instead of requiring several large units as working engines and spares, a number of smaller ones can be installed, with a resultingly smaller total horse-power installation.

That the combined efficiency of a gas-engine installation on a mining proposition would be much greater than with a steam-driven installation can be seen from the following:—

	Per cent.
1. Heat efficiency of gas-engines and producers, say, average of ... ..	18
2. Losses in Gas Mains, say ... ..	3
3. Heat efficiency of steam-engines and boilers, say, average of not more than... ..	10
4. Mechanical efficiency of generators, say ... ..	95
5. Efficiency of cables and lines, say ... ..	98
6. Efficiency of transformers, say ... ..	95
7. Mechanical efficiency of motors, say ... ..	92
8. Efficiency of shafting, say ... ..	85

Efficiency in each case means the percentage of the power put into the plant, which is delivered to the belt, coupling, or terminals, so that when gas-engines are placed fairly close to the generator plant, the total heat efficiency would be not less than 18 per cent. at normal working load, whilst there would be losses due to pipe friction, etc., amounting to an average of 3 per cent. on engines placed long distances from the producers,

giving a net heat efficiency of, say, 17.4 per cent. on these engines.

For the purposes of this paper, we can average the heat efficiency of all the gas-engines, on a mine completely equipped with them, at 17.5 per cent. The combined efficiency of producers, gas-engines, electric generators, transformers, transmission lines and motors, would be 14.25 per cent.

The net heat efficiency of drives consisting of steam-engines, boilers, and shafting, would average 8.50 per cent. For steam-engines, boilers, electric generators, transformers, transmission lines and motors, it would average, say, 8.15 per cent.

If we now reduce our efficiencies to a coal consumption basis, we can establish a medium for comparing the actual cost of delivering power to the various belts or couplings driven by the different types of plant. Various authorities give the mechanical value of a B.T.U. at from 772 to 778 foot lbs.—the author takes Joule's equivalent of 772 foot lbs. If we reckon that our local coal has a thermal value of 9,000 B.T.U. per lb., then :—

	Lbs. of Coal per Hour.
A heat efficiency of 100 per cent. would mean 1 B.H.P. for ... ..	.285
A gas set efficiency of 17.5 per cent. means 1 B.H.P. for	1.628
A gas and electric set efficiency of 14.25 per cent. would mean 1 B.H.P. for ... ..	2.000
A steam-engine (and boiler) efficiency of 10 per cent. would mean 1 B.H.P. for ... ..	2.850
A steam-driven shafting set efficiency of 8.5 per cent. would mean 1 B.H.P. for ... ..	3.353
A steam-engine and electric set efficiency of 8.15 per cent. would mean 1 B.H.P. for ... ..	3.500

Nine thousand B.T.U. per lb. of coal may seem low, but we have tests of local coal on record showing under 8,000 B.T.U. per lb. These, however, were probably of samples under the average.

(NOTE.—The shafting efficiency is for the average of the ordinary drives used on the mines, such as mill line shafts, machine shop shafting, etc.)

If a mine were equipped with a gas-driven plant, the arrangement would be somewhat as follows :—

The mill line shaft would be dispensed with, and 25 B.H.P. gas-engines would be installed to drive individual sets of ten stamps. A separate engine would drive the tailings wheel, its power being from 15 to 30 B.H.P., according to the amount of pulp to be lifted. Distributed throughout the mine and on the surface would be a number of gas-engines running pumps—these would vary from 10 B.H.P. up to 60 B.H.P. At each level, or possibly at alternate levels, would be installed a small gas-driven air compressor, for running rock-drills and small air-winches—the number and size of these would vary, but it

might be estimated that 30 B.H.P. would be required for each 10 stamps, and the sets could be arranged either 30 or 60 B.H.P. In the neighbourhood of the crusher station would be installed engines of various powers to run crushers, mechanical haulages, conveyor belts, etc.—these would probably range from 10 to 30 B.H.P. At all the chief points on the mine, such as battery, crusher station, cyanide plant, head-gears, and perhaps on one or two levels underground, a small direct-connected electric set would be installed to supply current for lights. The machine shops would have one or more engines, each of either 15 or 30 B.H.P. Hauling engines will be referred to later.

To summarise the power requirements, and compare gas-engines with steam-engines, it will be well to assume the case of a 100-stamp proposition. The whole of the previously stated efficiencies include transmission losses, and treat the power as the actual B.H.P. delivered to the various machines, so that we can make direct comparisons on the basis of the B.H.P. The average power required, exclusive of main hauling engines, would be, say :---

	B.H.P.
Battery, 100 stamps at 2.5 H.P. ... ..	250
Tailings Wheel ... ..	20
Pumps, including all types, say ... ..	150
Compressors, at 3 H.P. per stamp ... ..	300
Crushers, Mechanical Haulages, and Conveyor Belts, say	60
Cyanide Works, exclusive of Pumps, say ... ..	20
Tailings, Haulage or Conveyor Belts, say... ..	20
Electric Lights, say ... ..	50
Machine Shop, say ... ..	30
	<hr/>
Total ... ..	900
	<hr/>

This would be divided, in the case of gas sets, as follows :—  
B.H.P.

Direct Drives ... ..	850
Electric Drives ... ..	50
and the coal consumption per hour would be :—	
	Lbs. per Hour.
Direct Drives, 850 B.H.P. at 1.628 lbs. ...	1,383
Electric Drives, 50 B.H.P. at 2.000 lbs. ...	100
	<hr/>
Total ... ..	1,483
	<hr/>

The Steam sets would divide up to :—  
B.H.P.

Direct Drives through shafting—Mill, Tailings Wheel, Compressors ... ..	570
Electric Drives—Pumps, Crushers, Haulages, Cyanide Works, Lights, and Machine Shop	330

and the coal consumption per hour would be :—

	Lbs. per Hour.
Direct Drives, 570 B.H.P. at 3.353 lbs. ...	1,911
Electric Drives, 330 B.H.P. at 3.500 lbs. ...	1,155
Total ... ..	<hr/> 3,066 <hr/>

So that, during those hours when the whole of the plant was simultaneously in operation, there would be a saving by the gas plant of nearly 1,600 lbs. of coal per hour, or, averaging this through the 24 hours at a saving of 1,000 lbs. of coal per hour, the total saving per day would be, say, 12 tons of coal, or in the, say, 320 working days of the year, 3,840 tons. In other words, the saving per ton crushed would be about 50 lbs. of coal, or, if coal be taken as costing 10s. per ton, there would be a saving of 3d. per ton crushed, if the gas plant used the same quality coal as the steam plant. It would, however, use coal at least 2s. per ton cheaper, so that there would be a further saving of about £2,000 per annum, or a further 3d. per ton crushed.

If it was decided to instal a gas plant on a mine the first demand would be that all plant must be driven from it. It is impossible to couple gas-engines on to hoists, so one of two alternatives would have to be selected-- either the hoists must be electrically driven, or driven by compressed air. The latter system may seem absurd at first sight, but it has one great advantage-- a large reserve of power can be stored in cheap receivers, and the air being compressed in the same engine-room as the hoist, would be delivered hot to the pipe line, and would need very little re-heating to make it fit for working expansively in the engine cylinders.

It would take too much time to compare the relative advantages of the two systems, but even if electric hoists were installed, the current could be delivered to the hoists at a saving of 1.5 lbs. of coal per B.H.P. hour if gas-engines were installed instead of steam-engines to run the generators, provided the load was kept fairly constant. This latter condition is impossible, and it could only be expected that the cost of the current would be approximately the same in either case.

The exhaust gases from the engines working below the surface would need to be led to the ground level in light wooden shoots, being first cooled. Naturally small fans or blowers would be needed to give the required velocity, as the cooled gases would not otherwise travel up the shoots without back pressure being thrown on to the engines.

The maintenance and attendance costs for the engines would be very low. Once a gas engine is set running the only attention required is for lubrication, and, say, once a week, a little attention to the valves to remove any carbonised deposit. Practically no more care is needed than with electric motors, and certainly no more skilled attendance. A gas-engine can be

started up, and if its lubricators are all filled, it will need no attention for hours at a time. In these days of self-starters, there is no difficulty in starting up any size of gas-engine. The whole of the power-house and the greater portion of the boiler-house attendants would be dispensed with if steam were replaced by gas. The few attendants required for the producer plant would be recruited from the boiler-house staff.

The only remaining question is the capital outlay required for the two systems. In this connection we have most valuable and up-to-date information given us in the case of the Johannesburg Town Council plant. Alternative tenders were asked for both steam and gas-driven plants of the same size units, erected complete with all accessories.

There was practically no difference in the cost of the two systems, and when it is remembered what a large proportion of an ordinary mining plant forms spares for the balance (at least 25 per cent., omitting hoists), nearly all of which would be saved with a gas-driven plant, the balance for a mine would certainly be in favour of the gas sets.

As there would be about three to five different sizes of engines installed on one mine, it would only be essential to hold a reserve engine of each size, and spare parts. In case of a serious accident, the reserve engine could be installed, and in minor accidents spare parts could be put in. The most serious breakdown could be remedied with a minimum of delay and cost.

If one central producer plant served two or three adjoining mines, the capital outlay would again be reduced.

There is a final contingent advantage with a gas plant. All coal consumption on the mine would be localised at one centre. Gas would be delivered wherever required—for smiths' forges, smelting and assay offices, domestic cooking and heating, etc., and there would be a further large saving in this direction.

The author hopes that his remarks will induce those having the equipment of mines in hand to give more than a passing thought to gas plants, and if one or two seriously consider the matter, he will feel that his efforts have been amply rewarded.

## 34.—THE BACTERIAL PURIFICATION OF SEWAGE.

BY ERNEST S. PRENTICE, A.M.I.C.E.

(Plates XXXII. and XXXIII.)

There is an impression that works for the purification of sewage must necessarily be offensive to residents at hand, and that such works are a burden to the community for whose convenience they exist. I trust, therefore, the following account will help to remove this idea, and will convey some notion of the immense advances made in this subject of sewage disposal during the last 15 years. This account, I may say, is grounded largely on experiences gained as pupil and assistant of the late Sir Joseph Bazalgette, of London main drainage repute, and on other works of sewage with which I have been connected.

Until about the year 1890, town authorities, or other parties who desired or were compelled to purify their sewage, before discharging it into the nearest water-course, were for the most part brought face to face with great expenses, and often more or less insuperable difficulties. It may be said that until about this period the only process from which real purification might be expected consisted in passing the sewage on its arrival at the place of purification through a settling tank, in which tank were caught and deposited all the grosser matter in the form of sludge. More or less costly chemicals were often used for this part of the process, to expedite precipitation or render it more complete. The object of the removal of the grosser matter was to prevent the surface of the land on to which the sewage was afterwards passed from becoming clogged with solid filth, and so stopping filtration and giving rise to a nuisance. The sewage, after passing through and leaving the depositing tank, was run on to a large area of land, known as a sewage farm, and usually divided into plots. The flow of sewage over this land was continually watched day and night by a staff of men, and when one section was considered by them to have received enough, they diverted it to the plot next in rotation. The sewage was uniformly distributed over each section of ground by numerous trenches cut on the surface, from which it overflowed on to the adjacent soil. It then soaked away through the soil into drains laid at a lower level. Through these drains it passed in a more or less clear and inoffensive condition to the nearest watercourse. Between each flooding of sewage over the ground, intervals of rest were allowed for the sewage to drain completely away out of the soil, and for air to be drawn down into its pores for its thorough aeration. This aeration of the soil was indispensable to the conversion of the putrefactive nitrogenous matter in the sewage into non-putrefactive nitrites and nitrates. In other words, aeration was essential to purification.

These nitrates are the precise form of food required for the sustenance of plant life. With a continuous supply of such food to the soil, it was usually found advantageous to cultivate

thereon crops, such as wheat, beetroot, cabbages, etc. The sale, however, of these crops did little more than somewhat reduce the cost of working expenses.

With regard to the installation and maintenance of such sewage purification works, the chief troubles were, firstly, the difficulty, more especially in closely populated countries, of finding a large enough area of ground conveniently situated at a moderate price, and with soil of a porosity, suited for filtration purposes. For example, a town of 10,000 inhabitants might require a piece of land measuring a quarter of a mile by a quarter of a mile in area, and because of the not unreasonable opposition of residents and landowners at hand, the ground desired was often very difficult to secure.

After the land had been obtained, much labour had to be spent on its surface and in laying sub-drains before it was ready to receive the sewage. Moreover, much work had to be done on it annually afterwards, by ploughing and otherwise, to maintain the surface in proper order. After the working of the sewage farm had commenced, one of the main troubles was how to dispose of the sludge continually accumulating in large quantities in the depositing tank. In London, for example, sludge is taken by a fleet of six large steamers to sea, and there deposited. In inland and other towns it has been pressed by somewhat elaborate machinery into cakes, but this process is an offensive one, moreover the cakes are usually a source of trouble and expense to dispose of. Another serious difficulty occurs during continuous rains, when the ground through which the sewage has to percolate becomes water-logged, and the aeration of the soil essential to the success of purification is for the time stayed. At such times the sewage must perforce pass through the ground into the sub-drains and then into the river, with little or no purification taking place. Lastly, although the sewage farm may have been endowed with all the conditions for securing effective purification of the sewage, lack of judgment or carelessness in the supervision would often result in an evil-smelling works and the turning of an offensive effluent into the river.

Moreover, as towns increased in size and river conservancies became more insistent on the purity of discharges into streams, a solution of this sewage problem was more and more eagerly sought for. Many investigations were made with this end in view. Although it was well understood some time before the year 1877 that purification of sewage by percolation through natural soil was due to the combination of oxygen from air caught in the soil with the organic matters in the sewage to form nitrates, it only became known about this time that this combination was entirely brought about by what are known as aerobic bacteria, which naturally reside everywhere in the soil. It was found that if they were absent the combination and consequent purification could not take place. Aerobic bacteria are,



of course, bacteria to which a continuous supply of air is essential to their life processes. It having become established beyond question that real purification could only be effected by bringing sewage in contact with aerobic bacteria, experiments were directed to finding out a more rapid method of doing this than that through the natural soil. It may be said that the first practical outcome of the investigations for purifying town sewage on a large scale was the introduction by Mr. Dibdin, about the year 1890, of his artificial bacteria beds at Sutton, in England. Mr. Dibdin was then the chemist of the London County Council. The invention, if it may be so called, consisted of a series of five shallow reservoirs from 3 to 4 feet deep and about 30 by 50 feet each in area, made with concrete bottoms and side walls, very much as shown in that part of Pl. XXXII. marked "Bacteria Beds." These reservoirs were filled to the top, preferably with small pieces of coke or clinkers for the bacteria to cling to and reside in when the bed was in working order. The process was as follows:—The sewage on its arrival at the works was first passed through a strainer to remove the grosser matters, liable to choke the beds. It was then conveyed by a distributing channel (much as shown on Pl. XXXII.) to the coke beds one at a time in rotation. As each bed was filled, the sewage was allowed to remain in contact with the bacteria on the coke for about two hours. A valve in the bottom of the bed was then opened, through which the sewage escaped in a partially purified state into one of a set of secondary filter beds (not shown on Pl. XXXII.), in which it underwent further purification by precisely similar treatment to that in the first bed. From the latter bed it flowed off in a clear and inoffensive condition to the adjacent watercourse. It should be further explained that as the sewage escapes from the filter beds, such as these, air is drawn down into the interstices of the coke, from which the bacteria on the coke abstract the oxygen as in a sewage farm. The bed is then allowed to stand, aerating for three or four hours, until its time comes again to be flooded with sewage. When the beds are next charged with sewage the bacteria pass the putrefactive organic matter in the sewage through their bodies, with the result that the oxygen that they have absorbed enters into combination with this matter to form non-putrefactive nitrates. These can either be passed with the liquid filtrate, direct to the nearest watercourse, or used for the irrigation of land on which crops are grown.

What makes these artificial bacteria beds a far more economical and rapid means for purifying sewage than a sewage farm can be, is the fact that these beds can, if the available fall allow, be of any depth or thickness. The bacteria will establish and maintain themselves in these beds in the highest state of activity as readily and thickly in the lowest layers as at the top, whereas in the sewage farm they cannot usually live at a greater depth than 18 inches from the surface. This is owing



to the largeness of the interstices between the particles of coke, permitting the ready access of air throughout every part of the bed. Moreover, owing to the quickness with which the bed can be cleared of sewage after purification, and the rapidity with which air takes its place, aeration, instead of being a matter of days, as in the sewage farm, is only a question of three or four hours. Thus large volumes of sewage can be purified on a far less area of land by the artificial method than by the old sewage farm. It has been already mentioned, for example, that a town of 10,000 inhabitants might require a sewage farm a quarter of a mile by a quarter of a mile in area, or about 50 acres. It is possible to do the same work by the artificial process on one acre. Further, the distribution of sewage to the several beds and subsequent discharge from same, instead of requiring the attendance of a trained staff of men, day and night, is entirely effected by automatic appliances (not shown on plate). Thus the proper period of contact of sewage with bacteria and also of aeration is invariably secured. Further, the labour of maintenance practically disappears, and negligence and mismanagement, no uncommon occurrence in the sewage farm, become next to impossible. The constant feed of organic matters to the beds does not, as might be imagined, choke them up, for they maintain their capacity for sewage and work for years.

Although the Dibdin treatment in aerobic beds most effectually purified the organic matter in solution or finely divided solid matter in suspension, his process did not provide a means for the purification of the grosser organic matter. This Mr. Dibdin continued to remove from the sewage by the old method of screening. Here it may be said that Mr. Cameron, at that time city engineer of Exeter, stepped in and introduced the treatment now practised as preliminary to that in the Dibdin beds. This process is the well-known Septic Tank Treatment, and is shown on the left-hand half of Pl. XXXII. It may be said to be the first practical arrangement, on a large scale, for the purification of the grosser matter brought down by sewage. With the advent of this improvement the question of the complete artificial purification of sewage on a large scale may be said to have been completely solved, without any doubt whatever.

A septic or liquefying tank is usually a plain tank, with straight, vertical sides, in concrete, with a bottom of the same material, and may be either open or covered over. It is usually of a capacity to contain one day's dry weather flow of sewage, which is in continuous process of flowing in and out, by submerged inlets and outlets at opposite ends. Here the solids of all sorts are trapped and detained, until they have been brought to a liquid condition by an-aerobic bacteria resident in the tank, and in this liquid condition the former solids pass on to the coke beds. An-aerobic bacteria are, of course, bacteria which perform their life processes in the absence of air, and these, like

the aerobic, come down in the sewage. It is not pretended that there is no sludge at all deposited in the tank; what there is, however, is quite a negligible quantity in comparison with that left in the tank of the old sewage farm.

This sludge may be drawn off once a year, without offence, and without disturbing the top sewage. No chemicals are added to the sewage either in the septic tank or coke beds; indeed, chemicals destroy the bacteria and arrest purification. No offence whatever arises from the coke beds, and no smell is perceptible even to a person standing on the bed. There is only a faint odour from the septic tank at close quarters, and none whatever a few yards away. Neither is there anything of any kind soever to offend the eye in the appearance of the works or any product therefrom.

Not the least advantage of the bacterial system is its adaptability to dealing with the sewage and slop-water of private residences beyond the range of a town's sewers. Single houses, containing but a few individuals, standing in, say, only an acre of ground, can have their sewage purified by this means, on the premises, without offence to those residing there or neighbours. The entire sewage of many leading cities in England and abroad is now dealt with on the bacterial system, and it is now contemplated to deal with the whole of the sewage of London by this method.

The aerobic bacteria beds described so far are on what is known as the contact principle. There is, however, another method largely practised for bringing the septic tank effluent and aerobic bacteria together. This is known as the percolating system. By this method the septic tank effluent, instead of being retained in coke and bacteria charged tanks, is sprinkled over the surface of the bed, as on Pl. XXXIII. The even distribution of sewage is effected, as in the diagram, by a revolving automatic sprinkler, on the Barkers' Mill or recoil principle, or by other means. The sewage falling from the sprinkler slowly trickles through this bed, and passing through the bacteria on the coke in its downward course, falls on to the sloping paved floor of the bed, in a purified and clear state. From the sloping pavement it immediately drains into a culvert, wholly or partially surrounding the bed, and thence it is conducted either over a sewage farm or to the nearest water-course, as desired.

The advantages of this system are the extreme simplicity of the distributing appliances, and that the highest degree of purification can be effected without, as in the contact system, having to resort to secondary bacteria beds, before described. The latter involve a second set of automatic appliances, culverts, etc., for regulating and distributing the flow of sewage between the primary and secondary beds, which means considerable extra cost and attention. Further, the percolating beds, not being required to retain sewage in bulk, only for it to trickle through, the expense attending the construction of



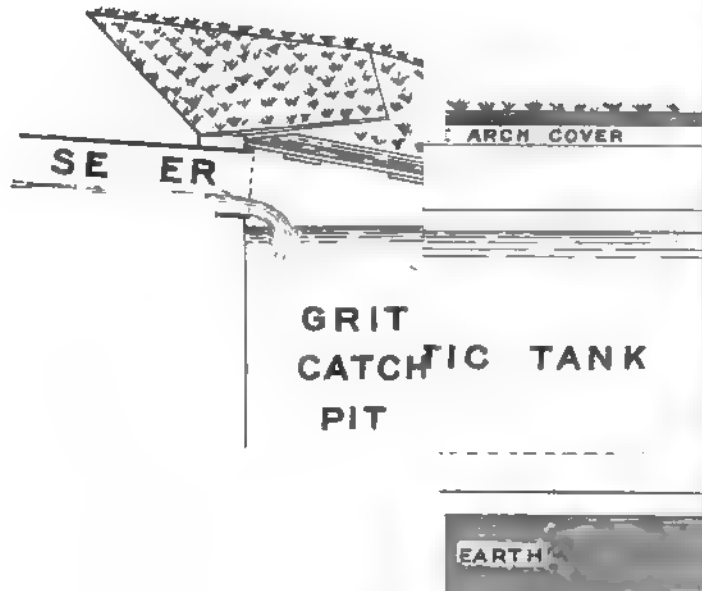




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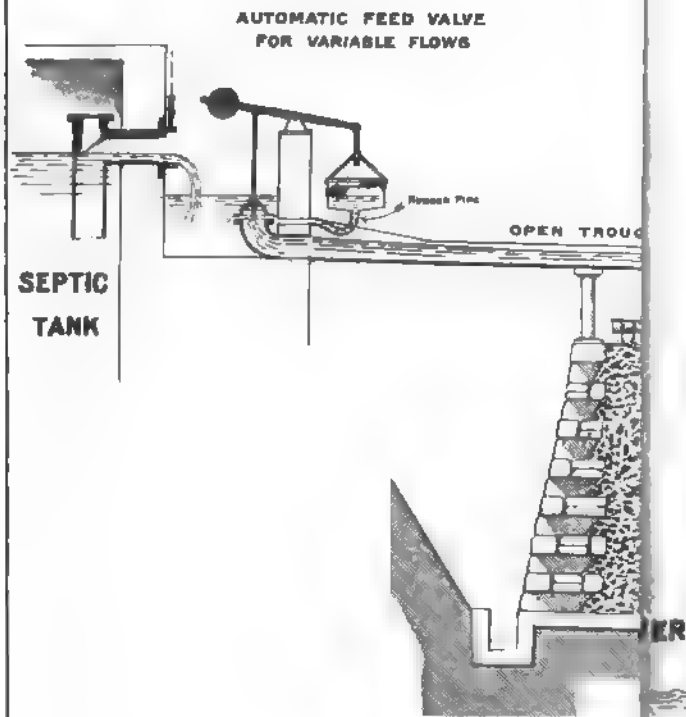
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## DIAGRAM OF AEROBIC





water-tight masonry side walls is not incurred. Bacteria beds, on the percolating system, are about to be installed for dealing with the sewage of Bloemfontein, and it is the system practised with success in England, for the cities of Salisbury and Chester and other places.

Comparisons between the pail system for collecting foul matter and water as now practised in this Colony and the water-borne and bacterial purification show that for every £3 now spent on rates by householders for the pail system, £1 would be saved by substituting the modern water method. Apart from the saving in expense, the benefit to health would be most incalculable.

EXPLANATION OF PLATES XXXII. AND XXXIII.

PLATE XXXII.—View of bacterial tanks for the purification of sewage.

PLATE XXXIII.—Section through aerotic bacteria beds on the percolating system.

## 35.—THE SEPTIC TANK TREATMENT OF SEWAGE.

By J. C. S. BEYNON, A.M.I.C.E.

Of recent years one of the most puzzling problems of the age has been the purification of sewage, for the methods adopted were totally at variance with the laws of Nature, consequently serious and costly failures were the result; but with the bacteria method a far happier and better light is thrown upon the subject, and I fully believe that the difficulties are now at an end. It is with great pleasure that I have the opportunity given me to explain to you the "Septic Tank System," which is the most successful method of bacteriological treatment.

"What is sewage?" It may be defined as "the liquid contents of a sewer." It consists of all foul water from town, or house, as the case may be, such as slop water, excreta, drainings of stables, and further, of dirty water from laundries, slaughter houses, waste water from dairies, and the washings from streets and back yards.

This sewage, carried in a pipe or drain to a common out-fall, used to be discharged into the nearest rivulet or stream, or, if a seaside town, on to the foreshore, where the tide was expected to wash it away; but after a time, as the villages or towns grew, the streams could not bear the strain, and soon became polluted, so that they themselves were nothing better than open sewers. In the same way with the foreshores; but perhaps this was even worse, as sea water delays the oxidation of organic matter, causing the solids to accumulate on the beach, and a horrible stench is emanated therefrom. When this state of things could no longer be tolerated, irrigation became the fashion, and the cry was, "Return to the land what you have taken from it," so the sewage was discharged on to the land in its crude state, but the ground soon became saturated, and the effluvia in the neighbourhood of these farms was what might have been expected.

Then the grosser solids were arrested by screening, but a large amount yet remained in suspension, and the ground had to be constantly hoed, as the pores of the soil soon became clogged with an impermeable coating, which solidified on the surface, keeping out the air, which was absolutely necessary for vegetation.

But this difficulty was seemingly got over by recourse to chemical precipitation, in which lime, alum, or a salt of iron were mixed with the sewage, the suspended matter being precipitated in the form of sludge, and this sludge was expected to be sold at enormous profits. There were also several other methods for the formation of this sludge, but, alas! it was soon found that there was no market for it, and instead of being of any value it soon became a nuisance and a difficulty to get rid of, and now cities like London, Manchester, and Glasgow ship this sludge out to sea, and dump it there at the cost of thousands a year.

In the case of the seaside towns the sewer was carried out sometimes several miles to a prominent point, and discharged into a tideway, in the hope that it might be borne away, but often it was carried back again, and crude sewage could be seen floating about.

No one, I think, can say that any of these methods has been satisfactory, and in the case of the chemical methods of purification it is now proved that they were totally wrong, inasmuch as they arrest decomposition, and kill the very means that nature provided for dealing with such matter; the result is an accumulation of solids, and when the effluent is allowed to discharge into a river, with all appearances of being clear and pure, under the altered chemical conditions it becomes foul and putrescent in a short time, putrefaction having commenced after being stayed for the period of treatment, and a costly failure has to be recorded.

The remaining system is known as the bacterial action, or natural means, and the septic tank treatment is worked on this principle, with the conditions made as nearly ideal as possible.

In 1895, Mr. Donald Cameron, who was then city surveyor of Exeter, had been busy experimenting, and the result was the septic tank system of drainage, in which the solid matter of sewage is capable of being dissolved and destroyed by the action of anaerobic micro-organisms.

Bacteria are very low forms of plant life, which feed on the organic matter and excrete it in a new form, its chemical composition as a rule being rendered simpler by the change.

In shape bacteria are in spheres, rods, and spirals; the spheres are often in chains like strings of beads, extremely minute, and never visible to the naked eye, but their power of multiplication is extraordinary and almost incredible: in 24 hours the number of offspring from each bacterium is computed to be 16,500,000 descendants, and in two days about 281,500,000,000. This would give about a solid pint of bacteria; this is what they might do if nothing happened to check them, but through the lack of food, or by the accumulation of their own excreted products, which are injurious to them, they in their turn die off, and are thereby kept within reasonable bounds.

The method of growth is by simple division or fission; each individual sphere elongates, and then divides in the middle into similar halves, each of which repeats the process, and so they go merrily on; another kind continues to increase in length, sometimes without showing any signs of divisions, and long threads are formed, but these after a time break up into short rods.

Bacteria have had a very bad name, and even in the popular imagination they are to be avoided at all risks, but this is a most difficult matter to do, as they exist almost everywhere on the surface of the earth; they are in the soil, they are in the

water, in the air, and you may be sure there is a plentiful supply of them in the Johannesburg dust; they are always to be found in excessive abundance in all decaying matter, but they will not do any harm, and are really agents for good, but like the "black sheep" which are in every fold, you may come across a "pathogenic" bacteria, which is capable of doing great injury, but these germs are very few compared to the great host of harmless species.

The benefits we derive from bacteria are enormous, and their aid is necessary in the manufacturing of linen, jute, and hemp, citric acid, vinegar, tobacco curing, butter, cream, and many other things.

Sewage that contains human excrement works its own destruction, as all faecal matter teems with bacteria; at the same time, it takes a little while for these busy "scavengers" to multiply in sufficient quantities to set up the required fermentation, or decomposition, which forms the scum, or leathery-looking layer, on the surface in the septic tank.

At Pretoria, for the new cantonments, I have just completed an installation for 3,000 people, which is now working, and giving satisfactory results, and perhaps it will be as well to give you this installation as an example, and to explain at the same time its working.

The installation consists of a grit chamber, with storm-water overflow, two septic tanks, and eight filter beds.

The grit chamber is for the purpose of catching all insoluble matter like sand, road detritus, and such like from passing into the tanks, and it is surprising what is found in this chamber. If the volume of sewage is too large for entering the tanks by the addition of surface or rain water, say from the roofs, and therefore diluted to a large extent, a storm-water overflow weir is placed in this chamber at high-water level, and is checked by a dipping slab, which keeps back all solid matter which would otherwise be washed on to the land. The sewage from this grit chamber passes into a channel, which conducts it to the intakes of the septic tanks, two in each chamber. The delivery from these intakes is two feet below the surface or low-water level; this is done to avoid disturbing the scum, and to shut off any air from entering.

These tanks are practically air-tight, being covered over with concrete arches, but provision is made in each tank for the escape of the gas generated, in order that they may not get too seriously charged, the depth below the springing at the intake end being 6 ft. 9 in., to 7 ft. 3 in. at the outlet end, and are constructed to hold 24 hours' supply, ordinary dry weather flow. The flow through the tank is continuous, and the effluent is drawn off 1 ft. 6 in. below the water-level, the effluent thereby passing off in an even stream by a 6 in. pipe with an half-inch slot, running across the end of the tank, causing as little disturbance as possible to the scum accumulated. Now, the ques-

tion naturally arises in your minds, what becomes of the solids—surely the tank must soon get full of sludge; but it is here that the micro-organisms start doing their work, and very effectual it is, consisting in the breaking up and liquefying, and ultimate destruction of all organic matters, and converting them into harmless compounds, such as nitric acid, carbonic acid, ammonia, and water, with a considerable amount of gas generated—viz., marsh gas (methane), hydrogen, and carbonic acid, the first two being highly inflammable gases, therefore no light should be allowed to go near these tanks, otherwise disagreeable consequences may ensue. At Exeter the works are lighted by the gas generated in the tanks, incandescent mantles being used, or otherwise the gas only gives off a blue, hot flame.

The action of the bacteria is, that any solids entering the tank, on falling to the floor are immediately attacked, and are partly rendered soluble; these particles become buoyant, owing to the gas generated and adhering to the sides of the solids, causing them to rise to the top, forming the scum mentioned. This action is constantly going on, until the matter finally falls back to the bottom of the tank in a black ash; this is inoffensive, and of very small bulk, and only requires to be removed at very long intervals.

Provision, however, is made for the clearing of this ash in all large tanks now by a slotted pipe, at the lower end of the tank, which, by opening a valve, is discharged through this pipe, and no disturbance is thereby given to the scum.

From this tank it flows into the effluent chamber, and from thence to the gear chamber, and into the filter beds, eight in number, or in two sets of four. The tank effluent is admitted to each filter in turn, through a valve, the working of which is automatic, and by a series of levers and buckets, the latter of which is emptied by syphons. The advantage of this gear is very great; its chief merit lies in the precision and certainty with which it does its work. Without its aid, two white men at least would be required to attend to the proper working of the plant, one by day and one by night. It is impossible under ordinary circumstances, and with the class of attendant usually available, to ensure the operations being effected with anything like the precision which is attained by this gear, whereby not only is the best work got out of the filters, but they are kept in a thoroughly healthy condition, with no risk of their becoming "sick" (as the term is), due to being asked to do too much work, not being properly aerated, or other various causes, which are bound to occur if left to the tender mercies of hand regulation.

To get real purification, the filtrations of sewage must be intermittent, and here lies to my mind the success of this system, each filter doing its proper amount of work, and then having its rest. Taking the four filters, you have one filling, another is full and allowed to remain full for a certain period,

and the other is either emptying itself or resting for a while. In the emptying the great thing is to get the discharge away quickly, so that air is sucked into the filtering material. The bacteria which do their work in these filter beds are quite different to those working in the tank, for those that do their work with light and air excluded are known as “anaerobic,” while these are known as “aerobic,” and require as much light and air as possible, and the work to be done consists in the oxidation of the ammonia formed in the tank. This is converted into nitric acid, which at once combines with the bases to form nitrates.

The filtering material should be either coke breeze, clinker, or cinder sifted through an half-inch mesh, and passed over another screen of one-eighth inch mesh, and so freed of all dust.

The filtered effluent has been constantly analysed by the foremost chemists at Home, and I now give you an average sample of tank and effluent taken on six different days in May, and ending June 8th, at Belle Isle, Exeter, at the installation there.

AVERAGE (GRAINS PER GALLON).

		Raw Sewage.	Tank Effluent.	Filter Effluent.
Total Solids ...	...	57.0	37.7	31.5
Mineral Matter ...	...	28.3	24.5	25.0
Loss on Ignition ...	...	29.0	13.2	6.6
Chlorine ...	...	6.05	4.6	4.5
Hardness ...	...	8.0	9.0	10.2
Nitrites ...	...	None	None	None
Nitrates ...	...	Traces	Traces	.91
Saline Ammonia ...	...	4.4	2.82	1.16
Albuminoid Ammonia ...	...	.74	.47	.11
Oxygen absorbed ...	...	4.3	1.4	.33

The following table shows the percentage purification produced by the septic tank process according to different observers, as judged by the removal of albuminoid ammonia, and oxidizable matters:—

Authority.	Albuminoid Ammonia.	Oxidizable Matters
Dibdin and Thudichum ...	63.2	80.9
Dupré ...	84.9	88.3
Pearmain and Moor ...	80.0	90.0
Perkins ...	64.4	78.7
Rideal ...	77.0	82.0

I have kept the effluent for months in my office, in a corked bottle, and only a slight smell is given off from it, whereas if all decomposition had not set in it would be highly disagreeable; this is a very practical way of testing.

This treatment requires very little supervision; at Pretoria a man visits the works once a day, say for half an hour, to oil the bearings and to supervise the working. The filter beds require the surface raked over occasionally, which can be done

by an intelligent native, and the grit chamber also requires cleaning out about once a week.

Very little smell is given off from this process, and it is free from any nuisance, and in many places large installations have been put down, where they are entirely surrounded by houses, which a glance at the photos taken of some of the installations will show. This gives it an enormous advantage, as the system can be put down in a town, and therefore the cost of a long length of outfall avoided.

The filtrate is a most valuable asset, as it can be used for irrigation purposes, more especially of the market garden class, and with the site so near the town is of much higher value than if seven or eight miles distant. Take, for instance, this town of Johannesburg; the installation could be situated close to the town, the filtered effluent could then be carried down the natural water-courses, the ground irrigated on either side, and the water after percolating the ground could be again collected in the spruits, and run into the dams, and used for mining purposes. I trust that this scheme may yet have the further consideration of our Council, instead of taking it miles out to a sewage farm, where they are proposing to erect septic tanks, the outfall sewer alone costing nearly as much as a complete installation. The ground required for an installation to treat the sewage from 60,000 people would only be about seven or eight acres, whereas with a sewage farm for the same number 120 acres will at least be required.

This system is now being adopted at most of the new cantonments in South Africa—viz., Pretoria, Standerton, Potchefstroom, and Harrismith—the effluent being used for growing vegetables for the barracks.

Several small installations have been put down for private houses, and the advantage need hardly be pointed out, when it is considered that water closets may be used instead of the smelly pail closet, with the added nuisance of having Kaffirs prowling round your premises at night time. Again, all your slop water, the bane of every householder, is at once carried away, and treated with the rest, your closets can be built in your houses, and all the comforts of Home sanitary fittings can be gained. The water bill is cut down by the fact that the whole of the effluent can be used on the garden, which means, with an average private house, about 150 gallons per day, or 4,500 gallons per month, of a value, say, 10s. per 1,000 gallons, equally £2 5s. a month.

These small installations are automatic in their action but require a certain amount of supervision to see to their correct working, but anyone who will take a certain amount of interest to comprehend the working will repay over and over again the little attention required.

A very important matter is to see that all grease is kept out of the septic tank, otherwise the liquefying action is seri-



ously interfered with, as the grease, forming a layer on the surface of the water, prevents the bacteria from doing their work.

I have been constantly asked, What would happen if typhoid or other pathogenic germs got into the tank? There is no doubt this is liable to happen, as persons suffering from certain diseases give off germs and organisms, capable of communicating the same disease to others, but in the tank and filter beds, the bacteria which are present in decomposing the sewage, destroys these disease germs, and Dr. Pickard, in his report on the Exeter installation, states:—\*

“ Since May, 1896, his attention has been directed to the influence of sewage upon disease germs, with a view to ascertain as exactly as possible the extent to which those disease germs were destroyed in their passage through the tank and filter beds. The typhoid bacillus had been taken as the germ to be investigated, and in his report he had set out the method and result of his several experiments. He had experimented upon the cultivation of typhoid bacteria in milk, broth, etc. The combined action of the tank and filters would pretty well account for the disposal of the typhoid germs. The vast majority would be destroyed. He had made a series of experiments giving the amount of energy in the bacilli which were left in the tank. He examined some storm-water sewage just as it would go into the tank. From the observations and experiments he had made, he was of opinion that the system of septic tanks and filters was an exceedingly good one in every respect, particularly in regard to its influence upon the germs of typhoid. His test was a very severe one, having to introduce a great number of germs in order that he might trace them in filtering. He had further made experiments with colour, to see if there was any streaming through the tank, and the result was very satisfactory.”

In conclusion, I wish to say that this paper is a description of the septic tank only. There are other methods in which bacteria play the prominent part, and as this subject is likely to be very much to the front in the near future in many of the towns in South Africa, those taking an interest in it should read the words of Dr. S. Rideal, D.Sc. (London), F.I.C., Mr. George Thudichum, F.C.S., Dibdin, F.I.C., F.C.S., and Martin, Assoc. Mem. Inst. C.E., who have treated this subject upon a much broader basis than I have been able to. But in bringing before you this system with which I have had practical and large experience, it is in the hope that your interest will be drawn thereto, and that when the question crops up again you may then be able to treat it in a manner which will enable the best results to be obtained, and I shall then be proud to remember that my efforts in the preparation of this small paper have not been in vain.

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\* Dr. Pickard, M.D., M.S., F.R.C.S., D.P.H., at the Local Government Board Inquiry held at Exeter, November, 1897.



## 36.—NOTES ON ITALIAN ARCHITECTURE.

By W. LECK.

In giving you a few impressions made upon me during a visit to Italy a few years ago, I have only touched upon a short period of Italian Architecture in a few buildings in one or two cities, and that you may in some manner understand how this Architecture came to be what it is, I will shortly explain its origin and development, starting from the time of the Greeks, though they themselves derived their inspiration from Egypt.

Few people visiting Florence, Venice, or the other towns of Northern Italy would dream of connecting the Architecture of the palaces with either Greece or Rome. Yet all European Architecture is derived from either one or the other, or from both, and much of it is influenced by the architecture of the East.

Greece produced her finest work between B.C. 480 and B.C. 430, and reached the height of perfection in the Parthenon, allowed to possess the most perfect proportion, beauty of detail and exquisite refinement of the arts relating to architecture, so that it stands alone: the glory of Greece and a reproach to the rest of the world.

When the Romans afterwards overran and plundered Greece, they carried back with them choice works of art, statues, pillars, and precious marbles, which they used in the construction of their public buildings. Greek manners, literature, and art became the fashion, and Greek artists flocked to Rome, but in the endeavour to please the luxurious and corrupt taste of their patrons, soon lost their purity of style, and their buildings though they far surpass in constructive skill anything the world had seen, could not be considered good works of art; nevertheless, they were designed on such a magnificent scale and with a grandeur in conception that the remains of these old Roman buildings to-day strike the beholder with awe and admiration. From the Greeks they borrowed the column and lintel, and from the Etruscans the semi-circular arch, and soon developed the Roman style of Architecture. One style grows out of another so gradually that it is impossible to say exactly where one ends or the other begins.

During the first three centuries of the Christian era, Roman Architecture reached its culminating point, and after the time of Constantine a gradual change took place which eventually produced the early Christian and Romanesque styles in Western Europe.

When Constantine settled at Byzantium, the Roman architects who followed in his train, brought their traditions with them, but different requirements, climate, and customs produced changes in the style of building, and we have the great Church of St. Sophia, Constantinople, erected by Justinian about 535, said to be the finest example of Byzantine Architecture, and perhaps the most beautiful of all domed interiors. I

only know it from photographs, but from them it appears to be all that is claimed for it.

Here the classic orders are no longer preserved in the construction, semi-circular arches spring from massive square piers, and support the glorious dome pierced by forty windows, arcades of rich marble columns with carved capitals support the galleries. Sculpture is almost abandoned, and the piers, walls, and dome are covered with grand decorative work in gold and coloured mosaic, the forerunner of St. Mark's at Venice.

The earliest architecture of Venice was Christian Roman, but only a few fragments are to be found, for Venice, though founded in 421, was only selected as the seat of Government in 809, when the Ducal residence was established there.

St. Theodore was the first patron saint of the city, and a church was erected in his honour on the present site of St. Mark's, but when the Venetians brought the body of St. Mark from Alexandria or Cyprus in 829, they made him their patron saint, using his emblem, the Lion, as their cognizance, but his body was consumed in a fire which totally destroyed the church in 976.

Pietro Orseolo very soon after began the existing building of St. Mark's, and with the assistance of Byzantine architects, the work was carried on for nearly a hundred years. The walls and domes were completed in 1071 and the church consecrated in 1085. The ground plan is in the form of a Greek cross, the arms being nearly equal, with a dome over each and a dome over the crossing. There are aisles to the nave and choir, and a large atrium or porch round three sides of the church, one being used as the Baptistery. The portico was intended for the use of new converts and the unbaptised, and that they might read a lesson, the domed ceiling is decorated with Byzantine Mosaics representing the Fall of Man and other important subjects till the time of Moses.

The great bronze doors leading into the nave are of Byzantine workmanship, incised and decorated with niello work, and are worthy of the place of honour, entering, the glory of the interior at once bursts upon you and you feel amazed, bewildered at the wondrous glory of the scene.

The building is lighted by arched windows all round the base of the domes, and by others high up in the walls, and they diffuse a soft subdued light in which one can realise the whole grand conception, the mystic domes resting on great arches springing from massive piers, pierced by arches, every part glowing with gold and coloured Mosaics or rich marble; and new lights and beauties revealed as you move from place to place. In the spandrils of the central dome are the four Evangelists, each with his name above. Between the windows the figures of the Apostles, and higher up still in the dome, flying angels support a sphere on which is Christ, and in all the domes there is the figure of Christ, in the utmost height of them, and so through all the church, Christ, Supreme!

Supporting the galleries are priceless marble columns, with exquisitely carved capitals and decorated arches, and separating the choir from the nave on solid plinth a screen formed by columns with well carved figures of the Apostles; on either side ambones or pulpits of marble and jasper, rich veined marbles of many colours everywhere, the floor of marble, serpentine and porphyry in undulations like soft swelling waves. St. Sophia, Constantinople, Ferguson says, has such a floor, and it is on record that it is an intentional symbolism, but having walked on that of St. Mark's, I can assure you it is not one to be recommended.

There are a few small figures on brackets and altar railings round the church and bas-reliefs of the Virgin built into the walls with softly glowing lamps in front.

Time will not permit all the wonders of the church to be described: the altar, with its shafts of, I think, onyx that you can see the light through, its arches, the wonderful "pala doro," only shown on certain feast days: the treasury, with its jewelled and enamelled cups and church vessels, and many other delightful works made long ago in the days when men loved these things. There is a magnetism about St. Mark's, and one is continually finding oneself straying in if only for a few minutes. It is a place to worship in, no other church I have seen seems so religious and helpful to one's inner nature. The church is neither large nor high, and this, I think, only shews what grandeur may be obtained by the lavish use of glowing colour, marble and precious stones in the hands of a consummate artist.

Can we not take a lesson from St. Mark's and make our churches glow with colour and rich marbles, "glorious without and beautiful within," full of symbolism and deep meaning, and the cross over all.

The best way to approach the church is by the upper end of the Piazza, long lines of arcades with elaborate windows and strong lines of cornices lead the eye to the further end of the square. At the right hand corner towered up—alas! lately fallen down—a great Campanile built of brick, simple and majestic, finished with an open arcaded belfry and pyramidal roof crowned with the gilt figure of an angel, and from the Campanile, and partly concealed by it, stretches across the Piazza the Church of St. Mark. In front of it rise the masts from which floated the banners of the old Republic, and countless numbers of doves flutter about and circle in clouds overhead. As one walks up the quiet slab-laid square, the fascination of this strange Eastern dream draws you on with its facade of deep porches and arched heads glowing with colour and round the walls of the porches, some in light, and some in shadow, are many shafts of jasper and variegated marble, their capitals lovely with interwoven bands of flowers and foliage, mystic signs, and the Cross everywhere; and above these yet another

range of white arches curved up into great ogee shapes with carved crockets like the foam of the sea, and in the midst of all gleam the bronze breasts of the Greek horses brought by Doge Dandolo from the East in 1204, and towering above all the white domes against the blue sky, all lovely in the sunlight like pearls, coral and opals. What a contrast this is to our sombre English cathedrals!

The Byzantine palaces of Venice have mostly disappeared, a lower storey here and an upper one there only remain showing a series of graceful arcades the length of the front. The Gothic palaces we all know and admire so much were built during the latter part of the 12th and the 13th and 14th centuries.

They are generally divided into three or four stories in height, separated by moulded string courses, the entrance is by an arched doorway, with a few steps up from the water. The second stage has a handsome window of five or seven lights, with arched head carried on shafts and filled in with tracery and smaller windows of similar design, sometimes enclosed by a square line of delicate moulding. The third stage is generally a repeat of the second, only less ornate, and not so important. Many had parapets, but they have disappeared.

The richer palaces were faced with marble of various colours, and many had the plain spaces between the marble windows plastered and decorated with coloured ornament, and discs of marble and serpentine and other stones.

One feature which adds such beauty to the Venetian palaces is the lavish use of columns to all window openings, they give richness, light and shade. In no other city are balconies seen in such perfection and so useful, projecting over the waters which lap the foundation of the palaces. It is delightful to stroll out and enjoy the evening air after a sultry day.

Drifting in a gondola along the silent streets on a summer day one can revel in the beauty and colour of these old Gothic palaces rising up out of the sea, ever varying with the graceful sweep of the Grand Canal.

Adjoining St. Mark's is the Doge's Palace, from which the other palaces derived the idea of the traceried windows. It is the most magnificent in Venice. It is three stages in height, the two lower stories consist of arcades, and were erected in the 12th century, the lower one is a simple arcade of pointed arches, resting upon circular columns, with richly carved capitals, the upper arcade has double the number of arches richly moulded, with circles above, cusped and carved and finished on top with carved string course. Between the columns there is a balustrade of small shafts and arches cut out of the coping. The upper stage supported by the arcades is about equal to the united height of the two lower stories, and is a plain wall faced with a diaper of delicate rose-coloured and white marbles, broken by a few large arched and decorated windows. Some think this building would look better upside down, and there can be no

doubt the original designer did not contemplate the upper stage, but there it is, and anyone who is not captivated by its unique effect, beauty, and charming colour, must indeed be difficult to please. The lower arcade has lost much beauty by the raising of the pavement of the Piazzetta some 20 inches, and also by the disappearance of the marble decoration in the spandrills of the arches.

Before leaving the Piazzetta, notice the two granite columns with their bases and carved Greek capitals, one surmounted by the bronze lion of St. Mark, and the other by the statue of St. Theodore on a crocodile. The shafts were brought to Venice by the Doge Michael as part of the spoil after the conquest of Tyre in 1126, and even then they were "antiques." One shaft is more slender than the other, but the great spreading capitals of white marble are designed and carved so subtly by the twelfth century Greek artist, that perfect harmony prevails, and there they have stood more than seven hundred years, perhaps the two most beautiful columns in existence.

In all Venice you will not find one single tower or palace built for defence; surrounded as she is by shallow lagoons, no foe could attack her, and to this fortunate circumstance and her constant trade and intercourse with the East we can attribute the light, elegant and rich architecture and love of colour so delightful in the strong sunlight under a blue sky; no other European people so clearly caught the true feeling and passion for colour from the East and made it part of themselves.

When Venice was building her fairy-like palaces, other Italian cities were erecting frowning fortresses and towers in their streets, from which they carried on war over the heads of the peaceful citizens. Yet Florence, Pisa, Verona, and Siena were building their splendid churches through all the troublesome times.

Wandering down the winding Via Cavour in Siena, and turning under an archway, at once bursts upon the view the Tower of Magnia, soaring up into the blue sky, wonderful, incomparable, this living exquisite shaft, truly "a thing of beauty and a joy for ever," yet it is only a plain square brick shaft with stone projecting battlements adorned with coats of arms and crowned with an open belfry; the shaft has holes left in it at regular intervals for fixing scaffolding round it, in which the doves now make their home.

Here we have a plain brick tower begun early in the 14th century, which, owing to its great daring and skill in proportion, makes your heart beat quickly when you suddenly come upon it unawares. No Mosaics or carving here to catch your fancy, only simplicity, form, the symbol of freedom, towering up into the sky. Rather a contrast to St. Mark's, which is all colour, and little study of proportion or architectural forms, yet we are ready to fall down and worship it also.

From this I think it is clear that architecture may appeal

to you from two causes, colour and form; the latter responds to the purer and finer fibre of one's nature, and to the people who live in temperate climes. On the other hand rich harmonious colour carries one away with a rush, it appeals to our more sensuous nature like weird or sad chords in music. If we had to own up, I think the great majority of us would go for colour.

The modern architect seldom has the opportunity of covering his buildings with permanent decoration, so it is all the more essential that form should be his chief aim: in form are included light and shade, great factors in successful architecture, but difficult to obtain in proper proportion in these days of small rooms requiring almost equal spacing of openings. Nothing is more deadly to the feeling of beauty than the dull monotony of repeating uninteresting features, but repeat the arches in the Doge's Palace, and you have beauty to your heart's content.

Form reaches its highest development in the human figure idealized by the Greeks in the statues happily saved from the general wreck, which now adorn the museums of Europe.

Who has not been lost in wonder when after a storm the rain clouds roll up the mountain side, and are tinted by the evening sun with orange and purple, or the burning gold and blood red of the distant horizon, with all the many varying shades of colour. Let us study these wonders in colour and form that nature reveals to us, for that way lies perfection.

## 37.—DOMESTIC ARCHITECTURE.

By E. W. SLOPER.

(Plates XXXIV.—XXXVI.)

No better means of approaching my subject occurs to me than to try and say something of the principal considerations that arise in the process of house building.

The sum to be spent is determined, the site chosen, and then it falls to the architect to consider what kind of a house will best meet the special circumstances of any one case. In this connection, no considerations are more important than those imposed by the conditions of site. Amongst these must, of course, always be included those of aspect and prospect, but to such it is hardly necessary to refer, as no architect can afford to leave them out. I am thinking now of the broader, and, perhaps, less definite considerations imposed by country, climate, and the character of surroundings. These, it seems to me, should carry weight second to no others, if the house itself is to be pleasant and harmonious.

### THE INFLUENCE OF COUNTRY, CLIMATE, AND SITE UPON DESIGN.

I propose to call attention to some actual examples which I hope may appeal to the members of this Association, as they do to me, as being pleasant examples of domestic architecture, possessing each a character of its own, traceable, as I think, largely to the influences I have referred to.

The illustrations I have placed upon the walls are, I may say, almost exclusively of modern work.\*

I have thus restricted my selection because whilst the picturesqueness and suitability of old work as to externals are generally acknowledged, it is sometimes objected that such places did all very well for our forefathers of a dozen generations back, but no rational person could now put up with the inconveniences they entail.

It is for us architects to show that whatever seeming antagonism there may be between comfort and beauty, it is seeming only, and can always be reconciled.

I am referring particularly to the work of two or three architects simply because I have chosen the readiest means at my disposal to illustrate my points, and because it seemed to me that these might possibly gain in precision by such a restriction.

The first group of illustrations is of reproductions of photographs of houses designed by Mr. Edwin Lutyens, which I have chosen as characteristically English. (See Pl. XXXIV.) The second group are sketches of houses from the designs of Mr. Lorrimer, of Edinburgh, chosen as characteristically Scotch,

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\* NOTE.—Of the illustrations exhibited it has been found possible to publish three only.



and the best photographs of houses in Mr Herbert Baker at the Cape are selected as characteristic of South African.

In the first set of designs there is something that at a glance resembles those typical houses of rural England, which are a mixture of combined solidity and refinement, which is surpassed in no other country.

Mr. Lutyens explains in using only such material as the native produces is natural at this and we may be pretty sure that the mass details will make such prominent features of the buildings as to strangers in the land but are taken from the habit of spreading oak walls and adorning the neighbourhood of the house.

As regards Mr. Lutyens's designs unmistakably natural. The average of recesses and spalling projection of walls, the thick walls and simple windows and a lot of desire for sun control by combined with cold and storm, whilst the simple broad surface of rough cast plaster relieved where necessary with graphic niches or pediments and the spalling and ornament in that relief are eloquent of the conditions imposed by the attending primary fact, which is the natural building material of the country.

Mr. Baker's designs I may be allowed to consider, are no less characteristic of South Africa. In a country of bright, hot sun, a house can offer no more pleasant situation than that of cool and shade. That is, I think, one of the dominating qualities of the style which Mr. Baker adopted at the Cape and which is given in See Pl. XXV.

But as far as we have only dealt with this consideration of the local character broadly comparing differences of style which have been induced by various differing conditions of climate.

If a house is to be set out happily upon its site, more than this is necessary. Let us leave England, Scotland, the Cape and come to our own country of the Transvaal—to our own city of Johannesburg. I need hardly say that a house which is appropriate upon the deep soil and amid the trees of Doornfontein is not necessarily suitable upon a naked, rocky kopje of Pretoria.

A somewhat rugged, severe house of very good itself may in the one case be most expressive of a natural propriety to circumstances and of very satisfying appeal, whilst in the other the same house might simply astonish by its crudity.

Such rocky, linear sites in such a sunny land as this, introduce considerations which are most fascinating to an architect.

It may be of interest to call attention to some attempts to meet them which are illustrated upon the walls. (See Pl. XXVI.)

Possibly to some none these buildings may seem to be too severe. But it must be remembered that for the softening in-



fluences which the development of the immediate surroundings of a house are properly relied upon to supply, time is essential. I ask you to remember this, because it is admittedly a principle of first importance (I shall refer to it again later), and it is one which we are often tempted to forget in the desire to obtain picturesque effects without its aid.

#### THE VALUE OF SIMPLE ROOFS AND WELL-PLACED CHIMNEYS.

The revolt against the deadly dullness of the very late Georgian domestic architecture in England led to an opposite extreme of admiration for this quality of picturesqueness in building. The extravagance became general, and the ill effects of it are felt in all the Western countries of Europe to-day, and in such a country as this of our own, which is dependent upon traditions received from them.

Perhaps this extravagance is nowhere more viciously indulged than in the treatment of the roof. I have placed upon the table a book containing reproductions of photographs of English cottages. Any who have time to look at them will, I think, agree that they are attractive examples of what is known as the "picturesque" in architecture. Yet examination will show that the roofs are in all cases exceedingly simple and direct; in fact, a critical examination by those who have received training as architects must prove that not only the builders of such houses did not try to break up the natural, simple lines of their roofs, but that by the grouping of chimney flues and the avoidance of windows in the roof, they did all in their power to preserve a maximum of unbroken roof surface. It is this simplicity of roofing, perhaps, more than anything else, which in domestic architecture gives the effect of *Restfulness*; a quality which many of you will remember Ruskin insists upon as of the highest importance in architecture generally. Such roofs, however, cannot be pleasing unless covered with pleasing material; and it has been one of the great stumbling blocks to good domestic building in this country, that there has been for this purpose such compulsion to the use of iron. Time is gradually correcting this. Tiles and shingle are already available, and we hear of slate becoming so. But for years to come the use of iron must in many cases prove a necessity.

In such it seems to me to be a good principle to try and make the roof as subordinate as possible to the general design, and to rely upon a widely projecting eaves—a feature to which iron readily lends itself. Such an eaves will invite the pleasing adjunct of a supporting cornice, and in any case will throw a most grateful shadow and afford a very real protection to the walls.

There is one other point in connection with external effect to which I should like to call attention in passing. That is, the importance of well designed and well placed chimneys.

An illustration is a good example of this, and I may again refer to the book of cottages; in which it will be seen that the builders of many of the examples therein contained seem to have concentrated their best powers of design upon this feature. Note, too, how in Mr. Lutyens' work the chimney is made use of to offer effective contrast to the low lines of his roofs. (Plate.)

I must not take up more of your time in contemplating externals, but ask you to pass on to some thoughts about the interiors of our houses.

#### THE BANEFUL INFLUENCE UPON HOUSE PLANNING OF SOME MODERN CONVENTIONS.

There are certain general considerations of planning so well understood that they need not detain us. No one purchases a site possessing a good view without seeing to it that the outlook from the principal rooms shall reap the advantage of it. Such considerations, too, as the desirability of avoiding the western sun and obtaining the morning sun are well known. I prefer to call attention to others which, as it seems to me, are more frequently neglected.

Perhaps one of the most important of these is the danger to fail to make the most of our opportunities by too ready submission to conventions. This is especially so in the case of small houses. The idea, for instance, that every room, however small, must be at least 10 to 12 feet high to ensure proper ventilation, is especially, I think, a pernicious one. Nothing is more generally destructive of the modest repose which is the chief charm of a well-designed cottage than misplaced and unnecessary height. In such buildings economy of cost is in 99 cases out of 100 of first importance; and we should recollect that to decrease the height to a minimum of reasonable necessity is to permit the extension of accommodation to a maximum of floor space.

It is not the low ceiling which is the general cause of "stuffy" rooms, but the failure to provide windows in more than one wall of a room or to take other steps to ensure cross ventilation. If we are to have cool, fresh rooms in the warm months of the year the need of cross ventilation is a pressing one, and we shall find that if it be attended to, we can dispense with the disproportionately large windows which are always destructive to good cottage architecture, and which, in this brightly-lit land, are sometimes, even in large houses, very objectionable.

It may be that we should wish in a particular case to take full advantage of a fine view from a particular room. If so we should, I think, do well to arrange the large windows that become necessary under the grateful shade of a stoep.

Another convention with which we are frequently trammelled is that which prompts us not to have our front door entering directly into a room. In the case of large houses that

is only reasonable. But in quite small houses, and especially in this country, where nine months of the year are warm, what good reason is there to give way to it?

In such little houses as we are just now considering, numbers of which are, of course, not designed by architects, much more than three feet in width is seldom allowed for an entrance passage. This is generally totally inadequately lit and ventilated through the front door, so that both by reason of the restricted space and prevailing gloom it is difficult to reach either of the little rooms, which we know await us to right and left, without collision with the umbrella stand. The gain is great if this entrance passage be thrown into one of the rooms, which then becomes a pleasant apartment, offering a comfortable spaciousness to its occupant and a cheery welcome to his visitors. A resulting difficulty in arranging the staircase need not be feared. A curtained arch can here be made a sufficient partition, and this is what has been arranged in a plan, to which I may be permitted to call your attention. In this plan a bookcase, it may be noticed, has been arranged behind the front door in order to screen the first entry of a new arrival, and by intercepting draughts to lend cosiness to the room.

I am well aware that objections can be urged to such an arrangement, but do not the material benefits altogether outweigh them?

#### SOME SUGGESTED REVIVALS IN HOUSE PLANNING.

In larger houses the revival of the use of the hall as a living room has become very general.

The Elizabethan plan adopted also in the old Dutch houses at the Cape of screening such a hall from the entrance lobby by means of a decorative wooden screen is one well suited for adaption here. If the house be sufficiently large to allow such a hall to embrace the height of two lesser apartments, a fine room should result.

Might we not consider the revival of another mediæval feature of house planning as appropriate to this country, viz., that of the internal courtyard? Some illustrations show how fascinating this feature can be.

#### CONSTRUCTIVE PRETTINESS.

Individual wants differ very considerably in a house plan, and have always to be taken into account. I do not propose to enter into any detailed consideration of them, but may I say a word in criticism of one general tendency of a very great deal of modern domestic architecture? A tendency to *constructive prettiness*, which is perhaps specially noticeable in interior work.

We all know the fireplace and overmantel sprinkled all over with shelves and nooklets innumerable—the queer angular recesses which do duty as cosy corners—the fretted woodwork

screens which take the place of the simple, straightforward arch—these and suchlike are, I venture to think, not commendable.

#### THE VALUE OF PROPORTION.

Architects soon learn in practice that it is an error to think that the more nooks and corners we arrange in our rooms the cosier they will be. What is of first importance in their design, as in all architecture, is good proportion, *i.e.*, the relation of length to breadth, of height to both, and the due subordination of lesser parts to the main body. Of course, the exigencies of house planning do not permit the observance of any strict rules of proportion. But the discerning architect will always bear their consideration in mind, and, by expedients which experience suggests, seek to mitigate the faults in proportion which he cannot avoid.

Of such faults the most general and difficult to prevent in the design of houses is an excess of width to length in the dimensions of a room. The limiting dimensions of a billiard room, for instance, 24 ft. by 18 ft., do not give a satisfactory proportion, and many will have noticed how much more pleasing is the result if, retaining the limiting width, the corresponding length is increased by several feet. In such a case we are often tied. But in other cases we have, I think, come to believe that a width is necessary which can, in fact, be quite easily reduced.

It is often said that a dining-room must not be less than 14 ft. in width. In a large house it may be advisable to make it wider. But in a room in which it is unlikely that more than six or eight people will sit down to dine, this dimension can be quite comfortably reduced by as much as 2 ft. Care only is needed to provide space for the sideboard at the *end* of the room, to avoid a projecting fireplace in the *side* of the room, and to select a narrow dining table. It is extremely likely that the economies of building which have led to the general adoption of internal projecting chimney breasts have given rise to such a prejudice. For it will be found that many dining-rooms which are said to be 14 ft. in width have in fact an available width of only 12 ft. 6 in., by reason of the projecting chimney breast.

But I must not be led into too many technicalities. I will only repeat that if we are to have restful and satisfying homes this question of proportion must never be out of the designer's mind, and when in response to it he has done the best he can for the general shapes of the rooms he must be careful to see that such adjuncts as bay windows and fireplace recesses are rightly related and subordinated to them.

#### FITTINGS AND FURNITURE.

A less important consideration, but one which is more generally appreciated, is the desirability of having such fit-

ments as bookshelves, window seats, china cabinets, dining-room sideboards, or dressers, etc., designed with the rooms to which they belong and built into recesses provided for them. No doubt such provisions add considerably to the initial cost of a house. But this is fully compensated by a corresponding saving in the expenditure upon movable furniture, and I think that some examples of rooms so fitted which I am able to illustrate will show that "the game is worth the candle."

I must content myself with a sentence about furnishing.

It is never easy to furnish well. In a country such as this where the selection is so limited it is very difficult. But we should always try to have our furniture in correspondence with our house, and if this happens to be a small one with an iron (or say thatched) roof, it is as well to avoid the elegancies of the late French styles, which were the product of a luxurious and thoughtlessly extravagant Court. I have exhibited a few illustrations of well-furnished rooms—some in the "grand manner," some in cottage style—all good of their kind, and for the examination of those interested.

#### THE SETTING AND GARDEN.

Lastly, let me say a few words about the importance of the "setting" of a house. If the general pictorial effect of a house is to be satisfactory, it is essential that at least that portion of the garden having intimate relation with the house should be designed in conjunction with it. It is very usual to think that this is not a portion of an architect's work: I venture to say that no architect who is an artist will be satisfied to leave it to another. The School of Landscape Gardeners, which flourished a decade or so ago, have, as far as the planning of gardens go, had their day. They were and are admirable horticulturalists; but their attempts to imitate nature, and their dislike of a straight walk, were contrary to the established taste of centuries, and as unreasonable as it would be to attempt to build a wall like the face of a cliff.

This has been a much-fought question. It would need a paper upon this subject alone to go over the field of battle again. All who make any study of contemporary building papers must have noticed that the majority of country houses in England at the present day having pretensions to really good design have gardens in conjunction which are laid out either by the architect of the house itself or by some other architect who has won special repute in this particular work.

Any who may have a house to build upon a small plot of ground I would especially beg to consider this question of appropriate setting. Apart from all consideration of effect, it is really astonishing how great an economy in the utilising of ground can be effected if every part of it is properly apportioned in relation to the house, and the actual site of the house

not finally determined until this has been done. Here again I must not be tempted to enter into detail, much as I should like to do so. But as in the other divisions of my subject I have ventured to attack some convention or other which has seemed to me to lack good excuse for its acceptance, so, with your permission, will I here. We all of us, probably, like to catch the sound of the gravel cracking under the wheels of our visitors' carriages as they bowl up to our front doors. Do we not, some of us who build upon small plots of ground, sacrifice too much for this satisfaction? Have we not all seen the approach drive which has left so little space for a garden that the poor little flowers have to stand in corners like punished children, or crowd into one forlorn little heap, surrounded by a sea of unsympathising gravel? Is it not better to run the gauntlet of an occasional storm that we may enter a wicket gate linked to the front door by an avenue of dancing flowers or by a pergola "hung about with trellised vine"?

#### EXPLANATION OF PLATES XXXIV.—XXXVI.

PLATE XXXIV.—An English House, Mr. Edwin Lutyens, Architect.

PLATE XXXV.—A Cape Town House, Mr. Herbert Baker, Architect.

PLATE XXXVI.—A House for a Johannesburg Kopje, Mr. Herbert Baker, Architect.



*E. W. Sloper: Domestic Architecture.*







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## 38.—LIGHTNING ARRESTERS FOR ELECTRIC TRANSMISSION LINES.

By L. WILMS, M.Inst.C.E., M.I.E.E.

(Plate XXXVII.)

The Transvaal, and especially the Rand, is well known for its severe thunderstorms. Every summer we hear of damage done to life and property. The severity of the storms in this district is mainly due to the dry condition of the air requiring a higher difference of potential between the clouds and earth to break through the high air resistance, than when the atmosphere is in a more humid state, as experienced in the home country. This is clearly noticeable in the so-called dry thunderstorms, in which far more damage is done than when the tension is partly relieved by torrents of rain pouring down.

A large amount of electrical work has been put down on these fields, and it is there where the effects of the severe storms make themselves so badly felt, as testified by the large number of armature and transformer repairs in the summer months.

Buildings, chimneys, bridges, ships, etc., require only protection against the direct effects, when being struck by forked lightning, the indirect effects due to induction or redistribution of electrical potential not calling for any safeguard whatsoever, as these effects are so slight that they do not endanger property or life.

The overhead wire circuits of electric power plants, on the other hand, are very susceptible to these secondary effects, and it requires careful arrangement of apparatus to protect dynamos, motors, transformers, etc., against these effects.

It very seldom happens that a line is struck direct, but if so the heavy discharge generally breaks down the nearest insulators and goes to earth over the iron line poles, only a part of the charge following the wires to their destination, there being dealt with by lightning arresters of an efficient type, or finding its way to earth over other parts of the plant and causing breakdown of same.

Besides the main flash there is often a number of side discharges within a circle of about 50 yards going to earth simultaneously. Overhead lines are often struck by these side discharges, and although seldom dangerous to life, the voltage is always sufficient to break down any weak points of insulation unless proper arrangements are made to allow of a harmless discharge to earth.

In every thunderstorm the circuits are affected more or less by the inductive effects of lightning flashes due to the disruptive discharges from cloud to earth or from cloud to cloud setting up strong magnetic fields, rising and falling in strength in a very short period of time, and thereby inducing E.M.F.'s of high voltage in the surrounding circuits.

Then we also have disturbances in the wires due to electrostatic induction. During a storm the air can be regarded as a

dielectric under strain. The clouds above are generally positive and the earth negative. When a discharge from above takes place, the point struck by lightning and the immediate surroundings alter their potential, due to the sudden charging with electricity of the opposite sign. This is at one equalised again by small currents of high voltage passing through the earth, and especially along circuits and pipes of lower resistance. These currents at the time endanger the insulation of the affected lines.

Hoisting ropes, battery plates, rails, railings, etc., become electrified in a similar manner by electro-static induction during a disruptive discharge through the air.

The writer has himself noticed heavy arcing across the joints of a light railway line during a discharge of lightning. The flash went to earth at least one-quarter of a mile away from where the writer was standing.

This redistribution of potential is often made very apparent by the phenomena of sparking between the platinum wires of switched-off incandescent lamps, or between the points in wall plugs, etc., during thunderstorms. The switches for this class of apparatus are generally single pole, so one terminal of the lamp or plug is connected to a mile or more of overhead wire and the other terminal to perhaps ten yards of insulated wire under roof between lamp (or plug) and switch. During a disruptive discharge in the air there is a sudden increase of potential in the outside line as against the short wire on the other side of lamp or plug; which charge redistributes itself by sparking across the lamp terminals, and perhaps from there breaking across the switch air-gap to other parts of the supply circuit.

If the discharge were of a lower voltage and longer duration the lamp filament would be sufficient to take the equalising current, but it is characteristic of these static or inductive high potential discharges, as it were, preferring to break across a quarter of an inch of space instead of passing through the lamp with its very slight self-induction formed by one or two windings of filaments. Probably a small amount of current passes through the lamp at the same time. Sometimes the lamp filament is broken down; at other times, again, the lamp is found intact after the discharge has taken place.

These electro-magnetic or electro-static effects are frequently increased by a quick repetition of flashes along exactly the same path through the air, between clouds and earth. Such successive flashes follow the same zig-zags through space as made by the first discharge. This is due to the old path of heated air forming a line of lower resistance for the following discharges, which in an infinitely small space of time have acquired a sufficiently high potential from the reserves of atmospheric electricity still left in the cloud, to overcome the

momentary low resistance of the air, this all taking place in such a short space of time that the spectator thinks he has seen only one flash.

The above theory is proved by large numbers of lightning flash photos, showing bands side by side following the same zig-zags. In the Transvaal the writer has often been able to discern a repetition of flashes with the naked eye.

Further, overhead lines become charged hours in advance, when a storm is approaching, especially where the wires pass over treeless ridges and down again into low-lying parts of the district. This silent charging of the circuits is assisted by good insulation of system, the whole forming the one foil of a condenser, earth being the other foil, with air and insulators as a dielectric.

Every now and again, when the circuits are in this condition, the increase of potential manifests itself by sparking between wires or apparatus and parts connected to earth, these discharges often breaking through two or three inches of air to get to earth.

Before discussing the means of protecting lines and apparatus, attention must be drawn to another source of danger to the insulation of circuits and apparatus—viz., electric surgings in cables or lines caused by sudden switching on or off of cables and transformers. This phenomena is strongest in circuits with high self-induction and capacity, such as circuits supplying induction motors or transformers through long underground cables or through overhead lines covering large distances.

The E.M.F. of such oscillations may reach a value of three or more times the actual working pressure, so that circuits of above-mentioned description undergo a similar risk of being subject to breakdowns in cables and apparatus, due to electric surgings, as when affected by lightning.

Cases of overhead lines being struck direct by lightning are very rare, the secondary effects making themselves more felt on account of their frequency. If overhead lines, transformers, motors, etc., are not connected with the supply station during storms, the sparking over in lines and apparatus as a rule does not interfere with the future working of plant, as these discharges are generally of a very small amperage, leaving only slight signs of their passage. This remark, however, does not apply to underground cables, where the insulation becomes punctured by the passage of these minute currents and may break down totally after the cables are switched on again.

When a system is under pressure, the small disruptive discharges due to the secondary effects of lightning start electric arcs fed by the supply current, thereby causing serious burn-outs at the points of discharge. Fuses are no protection against these breakdowns, as the damage is done in the short period of time required for the action of the fuse. Of course, an arc is

only set up if a discharge takes place from two or more mains of different polarity. It is only during very light discharges that sparking occurs from one point alone to earth.

The insulation of transformers, motors, and generators from earth alone is not sufficient protection against the effects of lightning, the static charges having a tendency to start disruptive discharges between any two coils or terminals in a machine as well as between coils and earth.

It is the writer's opinion that machines and transformers installed in the Transvaal should not have their castings earthed, as, in conjunction with a good system of lightning arresters, such insulation of machines, etc., is of great help when protecting electrical plant against the effects of an excessive difference of potential between apparatus and earth.

Where it is considered necessary for the safety of the attendant to have motors or transformers earthed, the connection is best made through a switch, which is automatically closed when the attendant opens the door of transformer or motor room, and breaks the earth connection when the door is closed again.

Protection against lightning effects is mainly gained by inserting in the circuits a number of points of still weaker insulation than found in machines or other apparatus; further, by providing choking coils between such weaker points and the apparatus, to, as it were, obstruct the passage, by means of the high self-induction of such coils, against any oscillations of very high frequency.

This is easily attained by placing spark-gaps between the various wires and earth near the apparatus to be protected, together with an arrangement of choking coils between arresters and transformers, etc. The spark-gaps could consist of any metal, and have a spacing just narrow enough to break down when under a pressure of, say, double the working pressure. Such arrangement would efficiently protect power circuits when without current or pressure, but if such arresters discharge under ordinary working conditions, the result is invariably a number of short circuits at the spark-gaps, attended by burning out of arresters and blowing of fuses.

This incident would save the transformer or motor, which without the spark-gaps would have a breakdown, but the delay and expense caused by re-insertion of fuses and fresh arresters, perhaps located at a far-away part of the plant, makes the necessity for improvement seriously felt.

The writer will now discuss a few of the best known types of arresters, and endeavour to explain their action in as few words as possible.

The first arresters used on low voltage lighting or power circuits were simply spark-gaps consisting of two or more ribbed brass plates, with an air-space of about 1-64th in. between the zig-zag planes of the brass plates. One terminal of



the arrangement was connected with one of the circuit wires, the other terminal with earth. These arresters were practically copies of the forms which were used to protect the telegraph lines. They effectually shut down the plant and were more or less burnt during any thunderstorms in the vicinity of the circuits.

Then we had the disc-arresters as suggested by Wirt. The arresters consisted of ten or more round metal discs slipped over an insulated bolt and separated from one another by thin sheets of mica. The top disc was connected with the line, and the bottom one with earth. The inventor's idea was that this arrester would silently discharge to earth any accumulations of atmospheric electricity before same had reached a potential high enough to break down the insulation of circuit by means of a disruptive discharge. However, this did not allow for sudden inductive or static effects.

These disc-arresters are now quite obsolete, as they hardly offer any protection, and generally become fused together at the edges of the metal discs.

For continuous current tramway circuits the Keystone Arrester was at one time largely used. The arrester consists of a closed marble box with two holes at opposite sides. Brass flaps are hinged to the sides of the box and carry each a bent carbon rod, the points of which form a short spark-gap inside the box. One flap is connected to the line, the other to earth. On a disruptive discharge taking place between the carbons, the heated air formed by the arc expands, and blows the two flaps away from the box, thereby considerably increasing the air-gap and extinguishing the arc. After this the flaps fall back in their old position and are ready for the next discharge.

This type of arrester is now seldom installed, as the arcs often damage the boxes, and sometimes the arresters are completely burnt out.

Arresters with spark-gap mechanically opened by means of an electro-magnet have often been tried, and in many places are still in use.

Such arresters generally have one loose spark-gap electrode fastened to a lever actuated upon by an electro-magnet, or the electrode is fastened to a moveable iron core, which is drawn into a solenoid upon passage of current when a discharge is taking place.

The magnet coils are generally connected between spark-gap and earth, and in consequence of their high self-induction often practically obstruct the way for the passage of oscillatory discharges of high frequency. This and the risk of burn-outs by arcs not being extinguished in time have prevented this type of arrester becoming popular.

The writer has often found these arresters with badly burnt coils and gaps after severe thunderstorms when used on 2 x 110 volts three-wire systems.

A well-known and extensively used arrester is the Wurts type.

Wurts' arresters are built in units for 1,000 volts each, and consist of seven independent metal cylinders placed in a row in slotted porcelain holders, the whole being mounted in a water-tight cast iron box, which allows of installing the arresters on pole cross-arms without further protection.

The seven cylinders are spaced with a clearance of about 1-32 in. from cylinder to cylinder. The two outer cylinders are connected to the lines of different polarity and the middle cylinder is joined to earth.

This gives a sparking distance of  $3 \times 1\text{-}32$  in. between circuits and earth for every 1,000 volts line pressure, or 500 volts line to earth (static pressure).

For higher pressures the number of gaps is increased in proportion to the voltage. At 2,000 volts there are six gaps from line to earth, at 3,000 volts nine gaps, and so on.

The metal cylinders are composed of an alloy of brass, zinc, and antimon, of which the makers claim that it will not sustain an arc or become fused by the dynamo current after taking a discharge to earth.

These arresters can only be used on alternating current circuits, as the arc-extinguishing action of the arrangement depends mainly upon the arc dying out at the moment the current is reversing its polarity, that is, when passing through zero.

The non-arcng of cylinders is probably more due to the cooling effect of the heavy metal parts than to the special composition of the alloy, as it has been found that other metals of ample dimensions show a similar action.

When the cylinders become heated the arcs tend to stick, with the result that the fuses blow during heavy lightning discharges across the arresters.

A 2,000 volt system protected by Wurts' arresters would have a sparking distance of  $6 \times 1\text{-}32$  in., equal to 3-16 in. to earth. About 10,000 virtual volts or 14,000 maximum volts would be the minimum pressure at which a discharge across the gaps could take place. This is under the assumption that the air is dry.

To secure efficient protection with this type of arrester, all apparatus, etc., must be able to stand a pressure between terminals and earth of about 4 to 5 times the working pressure, which calls for very high insulation of generators, motors, transformers, etc.

The General Electric Co., of New York, make a spark-gap arrester with resistance designed by Wirt.

This arrester consists of three independent non-arcng metal cylinders, with two spark-gaps of 3-64 in. each, and a special carbon rod of about 30 ohms, in series with the spark-gaps. The first cylinder is connected to one of the line wires

and the carbon with earth when used on a 2,000 volts circuit. The resistance is non-inductive.

With two arresters on wires of different polarity the current due to arcing cannot exceed  $\frac{2000}{2 \times 30}$  amp. In practice, however, it is found that the carbons, which are made of a mixture of carbon and clay will not always stand this amount of current, but often explode when a discharge across the gaps of two or more arresters takes place.

Another type of arrester, invented by Wurts, of the Westinghouse Co., is the Type K Arrester, for continuous current circuits up to 700 volts.

The instrument is single pole, and consists of two metal electrodes mounted upon a lignum vitae block, flush with its surface. Charred or carbonised grooves are provided for the discharge. A second lignum vitae block fits closely upon the first block, completely covering the grooves and electrodes.

The makers claim that disruptive discharges will pass readily between the electrodes over the charred grooves, which act simply as an electrical crack through the air, providing an easy path.

The resistance between the electrodes is said to be more than 50,000 ohms, and is always in circuit.

There being no room for vapour between the two tightly-fitting blocks, no arc can be formed, hence the makers claim that the arrester is non-arcing.

The arrangement is certainly a clever one, but parties using this arrester are not in a position to judge whether same is effective or not, on account of the inaccessibility of the spark-gap. Probably the instrument will take light discharges to earth all right, but the writer of this has his doubts whether it will handle heavy discharges of high amperage.

A very good arrester for continuous current, probably the best, is the Thomson Arrester. This instrument consists of two horn-shaped copper electrodes, forming a spark-gap, and placed between the poles of a horseshoe electro-magnet. One electrode is connected to the circuit, the other through the magnet coil to earth. The arc of the dynamo current, following a disruptive discharge, passes through the electro-magnet to earth, and creates a strong magnetic field, which blows the arc upwards, thereby lengthening and extinguishing same.

In the author's mind this is a very good form of arrester, although it has a coil of high self-induction.

By altering the electrodes so that the spark-gap length could be regulated, the writer has had very beneficial results on 2 x 110 volts three-wire continuous current lighting systems. The original gaps were too wide, and did not give sufficient protection to the dynamos, as was proved by various arma-

ture insulation breakdowns, before above-mentioned alteration was effected.

Another well-known arrester for continuous or alternating current circuits is the Tank Arrester, also originally designed by Wurts, of the Westinghouse Company.

This arrester, which has been extensively used on these fields, consists of an arrangement of three bare copper wire choking coils placed in each main, earth connections branched off between first and second, second and third coil, and between third coil and motor or generator, etc. These earth connections are made by means of flat carbons extending downwards, and adjustably supported over the centre of one of the three tank compartments, so that the carbons are partly immersed in the water. The tank is of cherry wood, which is lined with galvanised iron, connected to earth.

During thunderstorms the carbons have to be connected with the choking coils by means of plugs or switches, and a stream of water kept flowing through the tank.

The direct connections to earth through the water provide relatively low resistance paths to earth. The opportunities for discharge are three-fold, and thereby greatly lessen the possibility of failure due to the selective character of static discharges.

The choke coils offer a high inductive resistance in the direction of the apparatus to be protected, and at the same time tend to force the discharges across the low resistance paths to earth.

This is a very good arrester for low pressures, and when always under current. In practice, however, tank arresters are only switched on during thunderstorms, and are therefore of no protection during atmospheric potential disturbances in fine weather when the apparatus is not connected to earth.

Tank arresters have been used on circuits up to 2,000 volts. This, however, can only be called bad practice, as in the first place there is a large waste of current, especially if the water supply is muddy or contains acids or salts, and secondly there is considerable risk to life whilst attending to the arresters.

Another disadvantage is that it may be necessary to install a considerable number of tank arresters on a large power-distributing system, where long branch mains lead to separate motors or transformers. This, besides being expensive in first cost, entails special attendance in the form of a man walking around the property switching arresters on and off during the thunderstorm season.

Telephone disturbances are also often caused by tank arrester currents affecting telephone circuits in the neighbourhood, sometimes through induction and other times through current leakages from alternating current systems over the tank arresters and telephone earths.

A good arrester for high tension alternating current systems is made by Siemens and Halske. The arrester is the invention of Olschläger and Schrottke, and consists of two copper rods bent approximately to the form of half hyperbolas. The vertices of the two hyperbolas are brought to within a short distance of each other, the space between them constituting the sparking gap. One rod is connected to the line and the other to earth, and the two are supported on insulators and placed in a vertical plane opposite to each other.

When disruptive discharges take place across the gaps of arresters of different polarity the arc maintained by the dynamo current forms a moveable passage for the current, and is blown upwards by the repellent magnetic action of the current, which tendency is assisted by the heat effect of the arc. During the upward rise the arc is continually lengthened until the pressure of the system is insufficient to maintain the passage of current, thereby extinguishing the arc. The action is generally so quick that there is not time for the line fuses to be blown.

The author has used this type of arrester with good results on a 10,000 volt power transmission line. The spark-gaps were set at  $\frac{3}{8}$  in. for arresters under cover, which gaps had to be increased to  $\frac{1}{2}$  in. for arresters placed outside on the pole lines, so as to prevent arcing of arresters being caused by drops of rain short circuiting the gaps.

The short spark-gap makes this arrester very efficient, the only drawback being that occasionally the arcs have a tendency to stick near the bottom of the gaps, thereby pulling down the supply voltage, and causing some of the motors to pull up dead.

This deficiency can be partly met by using separate earth connections of high resistance for each line terminal. This has at times been effected by using separate iron line poles as ground connections. Owing to the difference of soil and the quantity of water contained therein, this does not always give satisfactory results.

The author has at times noticed arcs of small amperage sticking at the bottom of the arrester horns after a discharge of atmospheric electricity has taken place.

Dr. Benischke, of the A.E.G., Berlin, has designed an arrester which embodies the principles of the Siemens and Halske and the Thomson horn arresters.

The spark-gap consists of two brass rods, the middle parts lying in a horizontal plane, and the four ends bent upwards and outwards. Underneath the horns an electro-magnet with laminated iron core is placed, the magnet windings being so connected that the magnet remains always excited when the mains are carrying current. This arrester serves for alternating and for continuous current circuits.

In propositions where very short spark-gaps are required Benischke inserts resistances consisting of glass and india-rubber tubes filled with water and connected between spark-gaps and a small water tank to earth.

Only a very small current can pass through the water in the tubes without causing overheating and boiling of water. On high-pressure systems the current is kept low by lengthening the india-rubber tubes and thereby increasing the resistance.

As this apparatus cannot take heavy lightning discharges, other horn arresters with magnetic action have also to be placed in the circuits requiring protection.

Besides the arresters already mentioned there are numerous other types, the description of which would make this paper too exhaustive; the author has therefore only mentioned the most prominent forms.

Lightning arresters should be placed about half a mile apart on long distance power transmission lines. In any case this spacing should not exceed one mile, if breakdowns due to cracking of insulators are to be avoided. Line self-induction forms a great obstruction to oscillatory discharges passing from the middle of a long line track to the arresters placed at the two ends of the wires.

Some points on long lines seem to suffer more than others during thunderstorms. This is probably due to the selective character of static discharges, the oscillations forming standing waves along the line in a similar manner as produced in the vertical wires and coils of a wireless telegraphy system. The points with the highest static E.M.F. (that is at the top of the E.M.F. curves) are more endangered than the other parts of the circuit, and wherever insulator breakdowns due to thunderstorms have taken place, such spots should be specially protected by line arresters, even if arresters had been installed two or three poles away. In many cases the latter arresters can be removed to the line pole on which insulator breakdowns are frequent, without having to provide another special set of arresters.

The ends of long transmission lines are subjected to high oscillatory E.M.F.'s, probably to the highest static pressures existing on any part of the system during thunderstorms, and should therefore be specially well protected. Short side branches on the circuits do not appear to be affected so much from the effects of atmospheric electricity.

On long distance overhead alternating current systems the author uses an arrester-combination of his own, consisting of a system of choking coils, spark-gaps, and a small non-inductive water resistance.

For 2,000 volt three-phase circuits, three choking coils are inserted in each of the three mains leading to the machine or apparatus which requires to be protected.



Each coil consists of about 10 windings of rubber-insulated wire, wound with an internal diameter of 6 in.—7 in. To increase the self-induction of the coils the windings are then covered with a layer of soft iron wire, No. 16, 18, or 20, S.W.G., wound in and out of the coil around the insulated copper wires, the spacing between any two iron windings depending upon the size of iron wire and upon the amount of current required by the dynamo, transformer, or motor, etc., installed at the particular part of the system. As a rule 1-16 in. space between adjacent iron windings is ample for a circuit taking 10 amperes at 2,000 volts. On low tension circuits less iron should be used. With proper iron adjustment there is no appreciable loss or choking effect for a low frequency (50 cycles) working current, whereas the coils offer considerable obstruction to the passage of high frequency oscillatory discharges into generators, motors, or transformers.

Spark-gaps are branched off from the connection made between the first choking coil and the outside line

On a 2,000 volt three-phase system 2 gaps, each 1-32 in. wide, are required for each conductor.

From each of the three sets of double spark-gaps a connection is made to a carbon 9 in. long and  $\frac{1}{2}$  in. thick. The three carbons are 5 in. apart, and each is immersed 3 in. in the clean water contained in an eight-gallon iron tank. The tank body is connected direct to earth, where possible, by clamping the wire on to a heavy water pipe. No supply or overflow piping is required for the tank. During the summer it is sufficient to make up the water once every one or two months, the evaporation being very small, especially if the tank is covered with wood or other insulating material. Air-holes should be arranged for.

The insertion of this non-inductive water-resistance reduces the dynamo current arcing across two or more sets of arresters during thunderstorms to 10 amperes and less. The amperage can be regulated by altering the length of carbon inserted in the water. On circuits carrying pressures above 2,000 volts this is best attained by slipping a glass tube over the upper part of the carbon and making a joint between the lower end of the tube and the carbon by means of resin, shellac, or sealing-wax. This arrangement has the advantage that the amperage does not alter with the height of the water level, as long as this level varies only between the top and bottom of the glass tubes.

When reducing the amperage of the arcs across the spark-gaps down to 10 amp. and less by inserting the water resistance, the author finds that there is no tendency for the arcs, maintained by the generator current, to stick in the spark-gaps, and also the small current following an atmospheric discharge is not sufficient to blow the fuses. To attain this result the spark-gaps should not be made smaller than mentioned before.

The spark-gaps can consist of small round brass cylinders 1 in. in diameter and about 1 in. long. It is not necessary that they are made of any special alloy or non-arcing metal. The author has made use of Wurts' non-arcing metal cylinders when making his investigations, as these parts were available from the old arrester arrangements. When these cylinders were finished it was found that smooth round brass pieces were just as efficient.

The cylinders are best mounted in a row on a base of marble, porcelain, or other suitable material, the first cylinder being connected to the line near the choking coil and the last cylinder to the carbon rod terminal on the tank.

A good strong 10-gallon iron oil drum makes a very serviceable tank, the earth-wire being bolted or soldered to the outside of the drum.

The author has in many places inserted a No. 16 S.W.G. lead fuse wire between the spark-gaps and the carbon. This has not in a single instance been blown during thunderstorms.

Whilst testing these arresters, by short-circuiting all spark-gaps and having only the water resistances in circuit, it was noticed that when the water became heated after a short period of time, small arcs formed between the bottom part of the carbon and the fluid, that is, in the layer of gas surrounding the carbon points. These arcs came and disappeared in very short and regular intervals, causing periodical interruptions in the circuit. The periodicity of these interruptions could be increased by shortening the length of carbon immersed in the water.

The above is probably a phenomenon of the same kind as the Wehnelt interruptor effect. This would assist in breaking the arcs across the spark-gaps, should there be any sticking, not that any such tendency of arcs sticking has been noticed, when using this arrester combination.

To safeguard the plant from the effects of specially heavy discharges the author branches off two more rows of spark-gaps from the connections between the choking coils on each wire. On a 2,000 volt system there are four gaps of 1-32 in. each, arranged in series between each coil connection and a good earth, no water resistance being inserted. This also applies to outside arresters mounted on the poles for protection of line insulators.

Figs. 1 and 2, Pl. XXXVIII., illustrate the method of connecting the two systems of gaps to earth.

In Fig. 1 the wires A.A.A. are connected to the overhead line, and B.B.B. are for connecting to a 10 k.w. three-phase transformer on a 1,000 volt or 500 volt system. The top row of single spark-gaps is connected to earth through the water resistance. The other arresters lower down each have two gaps between choking coils and earth. To make the wires more distinct, the earth connections are covered at regular intervals



with white insulating tape, the conductor leading to the carbons of the water-resistance showing the spacing at double the length as compared with the wires leading direct to earth. To the right of the water receptacle a separate tank-lid with the three glass-covered carbons is shown.

Fig. 2 shows part of the interior of a transformer house for a 2,000 volt single-phase system. The double sets of spark-gaps at the extreme left are connected to the carbons in a temporary receptacle on the floor, there being two gaps in each connection. The other arresters have each four spark-gaps between choking coil and earth. Only one of the four choking coils is visible, in the top right-hand corner of the figure.

When arranging the central station, three choking coils are placed in each feeder wire, and two rows of four gaps each branched off to earth for a 2,000 volt system. Only one tank with three carbons is required for each voltage at the station. Each carbon is connected to one of the three switchboard-bus-bars through a 2-gap arrester.

On 1,000 and 500 three-phase systems the arresters connected to earth have two spark-gaps for each main, and only one gap for the earth connection *via* the water-resistance.

The low-tension lighting mains require each a set of choking coils, and the branches to earth only one gap, 1-32 in., without any insertion of water-resistance.

Sets of arresters, choking coils, and tank should also be inserted where underground cables are connected to overhead mains, as otherwise the cables, especially at the points of entrance and exit of current, will act as lightning arresters, taking away any excess of static electricity in the overhead mains, and thereby breaking down the underground cable to earth.

Arresters with water-resistance earth-connection are also of value to protect a purely underground system of cables and apparatus of high self-induction, such as motors, transformers, etc., against a sudden increase of potential due to electric surgings caused by switching on or off circuits of high capacity and self-induction. Separate spark-gap arresters with direct earth connection are not required in underground cable systems having no long overhead line extensions.

The author arrived at this combination of short spark-gaps and water-resistance as follows:—The 2,000 volt portion of the East Rand Proprietary Mines' three-phase system was originally protected against lightning by a combination of ordinary choking coils and Wurts' non-arcing arresters. Six spark-gaps, each 1-32 in., were inserted between each main and earth at points where protection against atmospheric electricity was required. This arrangement would rarely form a passage to earth for pressures less than about 10,000 virtual volts or 14,000 maximum volts. The 2,000 volt transformers connected to the system were not built to stand this heavy strain, and in consequence one or more transformers were dam-

aged in every thunderstorm season. Besides this the high number of gaps did not always prevent an arc sticking in the arresters and occasionally blowing the line fuses.

To make the protection more efficient, iron-wound choking coils were then inserted, and the number of spark-gaps reduced from six to four.

This effectively protected the transformers, and no further burn-outs occurred, but owing to the reduction of gaps the blowing of line fuses during thunderstorms became very frequent indeed.

The author overcame this last-mentioned difficulty by inserting a water-resistance in the earth-connection, and then found that the number of gaps could be further reduced to two, as mentioned before, thereby decreasing the strain on transformers during static disturbances to about 4,000 volts, in place of the original strain of about 10,000 volts (virtual), when having six gaps to earth.

The new arrester arrangement was installed on all the circuits at the East Rand Proprietary Mines in the latter half of 1903. Since then the plant has run through the thunderstorm season without a stoppage or breakdown of transformers, motors, or generators, from the effects of lightning.

Line earths are easily detected without shutting down the plant by short-circuiting one arrester gap by means of a loose piece of metal laid across, and by bridging the other with the moistened end of an otherwise perfectly dry stick. If there is no earth on the mains, only a small static spark across the last-mentioned gap will be noticed; on the other hand, a fault to earth on one of the mains will show itself by a more violent arc of about 10-15 amp. across one of the short-circuited gaps of any of the two other mains, when earthed separately through their respective spark-gaps and water-resistance. The arc goes out as soon as the loose piece of metal across the next gap is removed.

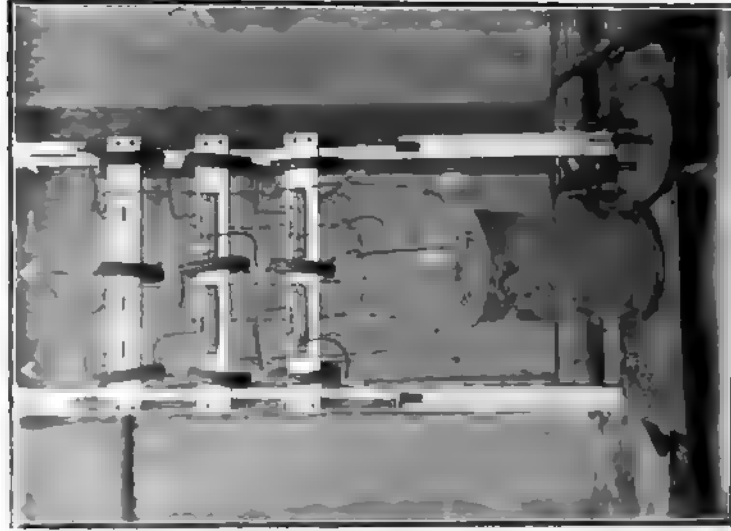
Before concluding the author wishes to point out that there is no danger to life when handling the water-resistance or carbons, as all this is directly and always connected to earth. There might be a question of risk during thunderstorms when discharges are passing over the spark-gaps to earth; however, no man in his right senses would try to interfere with these parts during a thunderstorm.

The author trusts that these investigations will lead to further improvements in the protection of the large electric power plants on these fields, and provoke a healthy discussion on this important subject.

#### • EXPLANATION OF PLATE XXXVII.

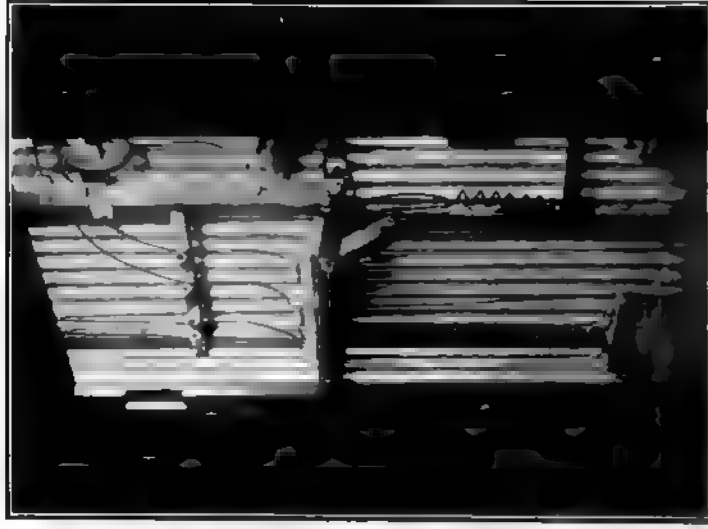
FIG. 1.—Lightning Arrester for 1,000 Volts Three-Phase System.

FIG. 2.—Lightning Arrester for 2,000 Volts Single-Phase System.



**Fig. 1.**

*L. Wilms :*



**Fig. 2.**

*Lightning Arresters.*



## **SECTION D.**

**ARCHÆOLOGY, EDUCATION, MENTAL SCIENCE, PHILOLOGY,  
POLITICAL ECONOMY, SOCIOLOGY, STATISTICS.**



## SECTION D.

### ACTING PRESIDENT'S ADDRESS.

#### THE EDUCATION OF EXAMINERS.

By E. B. SARGANT.

(Plates XXXVIII.—XLIII.)

#### EXPRESSION OF REGRET THAT PRESIDENT SHOULD BE UNABLE TO ATTEND.

The reason for my occupying the chair in this section of the South African Association for the Advancement of Science must, I think, be known to most of you who are present here to-day. I replace, all unworthily, a man who stands second to none among the notable pioneers of Johannesburg; one as remarkable for the fertility and soundness of his imagination as for the power of his pen; a great industrial leader, and at the same time a writer who has done more to make Englishmen understand the difficulties against which the industries of this country have had to struggle than any living man. From the author of the "Transvaal From Within" you would have had a presidential address that in itself would have sufficed to lend distinction to this meeting.

But it has been fated that, at the very time when his address would have been in course of preparation, Sir Percy Fitzpatrick should be prostrated by an illness in the course of which life itself has hung in the balance, and from which, even now, he is only slowly recovering. During that time of suspense, when we all shared the dreadful fears and anxiety that were borne, in a measure of which I hardly dare to think, by his noble and devoted wife, it was not the brilliant writer or the philanthropist or the financier of whom his friends, and even his many acquaintances, chiefly thought. It was the kindly host, the witty and humorous, yet ever simple comrade, the indefatigable friend, the staunch ally, that was present to their mind's eye. And now that he has so far recovered as to be able to receive communications from the world beyond his sick-room, I think that you would all like me to send a message to the president of this section, telling him how sorry we are that he is not among us to-day, and wishing him a quick and full recovery of his powers.

SUBJECT UNDER CONSIDERATION APPLICABLE TO ALL SUBJECTS IN  
SECTION D.

The subject that I have chosen for my presidential address may at first sight seem far from inviting. Yet, in spite of the unusual title of my paper, I undertake to say that most of you present here to-day will follow the results which I shall lay before you with ease, and will find a growing interest in certain ideas which cannot but prove novel to those of you who have not before thought of examiners as belonging to the human race and therefore capable of education.

In a sense we are all examiners. We note and tabulate events and their causes. We distribute mankind into ethnological groups, or compare them as industrial workers. We ascertain their wants and their means of satisfying those wants. We examine and record the growth of custom; the physical and mental development of the human being; the changes in the mind itself and the order of such changes; the ripening and decay of language; the distribution of wealth; the progress of society. Even the laws of statistics are submitted to examination.

Thus, side by side with the advance of theory in connection with all the sciences that fall under this section (archæology, education, mental science, philology, political economy, sociology, statistics), goes the scrutiny of results. It is justifiable, therefore, to think that an examination of methods of examination even in connection with only one of those subjects, will throw a light upon such methods in general. I propose to-day to consider that small part of education which consists in the testing of the results of study by written papers.

## GENERAL INTEREST IN METHODS OF EXAMINERS.

Who in this hall has not at one time or another undergone the ordeal of an examination, and who, before entering the examination room, has not trembled at the unknown body of inquisitors whom he may never meet face to face? Who has not come out, after some paper or other, burning with indignation at the tortures inflicted by one or more of this savage race?

Is it too much to say that, if a method were laid before you, by which it would be possible to exhibit the weaknesses of the examiners themselves in as clear a light as they expose the failings of others, everyone present would be interested in the unfolding of such a scheme of retaliation?

The little fish which lurks at the bottom of the stream, waiting for its accustomed food, and obliged to decide in an unnaturally short space of time whether a juicy worm that floats past it has, or has not, a hook concealed within its substance, might be likened to the ordinary candidate nibbling at an apparently innocent question in his examination paper. The angler with his rod and line, patiently casting his bait



from behind a bush, resembles in some candidates' estimation that unseen force, the examiner. Would not the trembling fish, I ask you, rejoice if, in its turn, it could insert a hook between the angler's jaws and dangle him before the public gaze as the unjust destroyer of all its watery happiness? Or if the sparrow pursued by the butcher bird, and almost at the point of execution, found means to turn and rend its adversary, would not its feelings be those of the examinee enabled, of a sudden, to chase his examiner? Or should the goose which was already almost plucked—— But, ladies and gentlemen, these similes are carrying me too far. I will content myself with the assertion that examiners are not always infallible, and that their infallibility can be demonstrated by methods which I am now about to consider, and which even a child can use.

#### MY OWN ACQUAINTANCE WITH EXAMINERS.

You will perhaps wonder how it is that I have taken such an interest in the doings of this gentry. The fact is that I am one of the few persons who has been for a lengthy period in the position of an examiner of examiners. In the post which I held in the Civil Service Commission for nearly fifteen years, it was my daily task to consider the character of the papers, set by some of the highest dignitaries at Oxford and Cambridge and other Universities, to candidates for posts in the English Civil Service. I had, moreover, to investigate the marking of the written answers of candidates, and to say whether the general results appeared to me to be fair and trustworthy. You need not be afraid that I shall reveal any prison secrets. I am not able to do so. The whole apparatus of the examiners' torture-chamber is safely lodged within the walls of Burlington House and cannot be produced on this occasion. Had the invitation to deliver this address been forthcoming at an earlier date I might, indeed, have sent for the instruments which I used on many occasions, and have laid before you (of course without names or any indications which could assist you to detect the unfortunate culprits) the testimony of guilt which was supplied to me by their own examination results.

#### GRAPHICAL PRESENTATION OF EXAMINERS' RESULTS.

Of course it will be understood that there are good as well as bad examiners; and that, in the remarks which I have just made, I am only alluding to a certain small proportion of the total number of those who have come within my range of observation. If the methods of good examiners are compared together, it will be found that they tend to uniformity, and that their results have certain characteristics in common. Whereas the methods and results of bad examiners differ from one another in every conceivable way.

But how are these results to be shown? It is not possible to obtain such information by running the eye down the totals awarded to candidates in the mark sheets. Patient study will no doubt do something, but where figures occur irregularly it is hard to appreciate their import without definite classification.

I remember a case in point. One of our newer examiners had made a great flourish as to his capacity for, and experience in, adjudicating on handwriting. I handed over to him a batch of papers written by a large number of candidates for female clerkships in the Post Office. Up to that time he had only examined men, and was duly impressed at being asked to mark the handwriting of the other sex. "The work of ladies!" he exclaimed, "then I must do them more than justice." As a matter of fact, when he returned the papers, I was convinced that he had done them much less than justice. But the difficulty was to convince my Commissioners, without asking them to inspect a large number of individual papers, that the distribution of marks was altogether wrong. So I drew a horizontal line on a piece of paper and erected vertical lines at equal distances along this base. Candidates who had received from nothing to ten marks were placed upon the left-hand vertical line and represented by dots at equal spaces apart; those between 11 and 20 upon the second, and so on; the final vertical being reserved for candidates between 91 and 100.

The result was a figure of this sort for 100 candidates (Pl. XXXVIII.), showing that, though the average mark was nearly 50, comparatively few candidates received an award of about that amount: many more, for instance, obtaining about thirty or about eighty. The marks were rejected, and a new examiner appointed.

This was, of course, a rough and laborious method. In these days of the almost universal use of "squared" paper, all that is required is to find the percentages of candidates obtaining marks between the limits named, and to mark them off by counting the squares, say five candidates to a square. If the maximum in the subject is not 100, then it is only necessary to reduce the marks to that scale.

By joining the top points of the vertical lines, which we call ordinates, the characteristic curve of the examiner is obtained; or, what is even more satisfactory, if black columns are raised on the bases 0 to 10, 11 to 20, etc., to show the number of candidates within these limits of marks, the result is a number of stepping-stones, shown in silhouette, and rising and falling in general harmony with the curve. The area of the black portion clearly represents 100 candidates, and is, therefore, always the same, however the candidates are distributed. The base line is called the line of *abscissae*. By rounding off these steps, so as not to interfere with the area of each column, we please the eye and enable it to draw inferences with greater ease. It should be observed

that the number of candidates is not given any longer by heights. The method of representation by areas will, however, only be introduced at a later stage.

#### APPLICATION TO SIMPLE CASES.

Before dealing with complicated examination results, I wish you to consider with me the very simplest form of question which could be proposed to candidates, and, with the aid of a diagram such as has just been exhibited, to fix in your minds the conclusions at which we arrive.

In the first place I will suppose that an examiner asks a hundred candidates a question to which the only reply is "Yes" or "No," and I will show the marks obtained for that question upon the diagram before you (not printed), which consists of a square divided by horizontal and vertical lines into a hundred smaller squares.

If the question were infinitely easy, all the candidates would answer the question right and would receive full marks. Each vertical space representing five candidates, and each horizontal space ten marks, and 100 marks being given for a correct answer, you will see that a dot placed twice as high as the top of the diagram upon the right-hand bounding ordinate would represent the distribution of the candidates.

But now suppose that the question were infinitely difficult instead of infinitely easy. In this case you might think that the whole number of candidates would leave their answer-papers blank and obtain nought. The dot representing their performances would, then, be placed in a similar position upon the left-hand bounding ordinate.

That would, no doubt, be so, if all the candidates were infinitely conscientious. But, should the candidates not all be of this type, they, or their private tutors, might say: "If a question only requires the answer 'Yes' or 'No,' it will be best to put down one of these two answers at random on the chance that it may be right." And, on the supposition that all the candidates were infinitely unconscientious, about fifty candidates would say "Yes," and about fifty "No." The equality would be necessarily absolute if we were considering an infinite number of candidates and reducing to a percentage. We shall have, therefore, to put two dots at the two top corners of the diagram.

In this connection I am reminded of a story of my school-days, which I trust that you will forgive me for interpolating here. One of the masters had been lecturing to the Sixth Form for some weeks on the Catiline Conspiracy, and gave them an examination paper to test their knowledge of this portion of Roman history. He asked some such question as "Was Cæsar privy to the death of Catiline?" A humorous member of the class simply answered "No." Being dissatisfied with the results of the examination, the master told his boys to read

up the period once more, and then set another series of questions, which were altogether fresh, except that he again inserted in the paper, "Was Cæsar privy to the death of Catiline?" The same boy on this occasion answered "Yes." Sent up to the head master on account of these two monosyllabic and contradictory replies, the boy pointed out the absurdity of the form of the question and escaped with a mild rebuke. I have little doubt that the master who had thus complained of his outraged dignity heard something much more caustic from his chief in regard to his capacities as an examiner.

But let me pursue this study of the infinitely unconscientious candidate (which the one I speak of was not) a step further. I will suppose that two questions are set instead of one. In this case the candidates will be divided into four equal groups: those who answer both questions right, those who answer the first question right and the second wrong, those who answer the first question wrong and the second right, and those who answer both questions wrong. The result is that one-quarter of the candidates obtain no marks, one-half obtain half marks, and the remaining quarter full marks. This is shown on the diagram by three dots, of which the middle one is raised twice as high from the base as the two extreme dots.

With three questions the relations between the ordinates taken in order are 1, 3, 3, 1; with four questions 1, 4, 6, 4, 1; and with five, 1, 5, 10, 10, 5, 1. In each case the ordinates are, in mathematical language, proportional to the coefficients in the binomial expansion of corresponding degree.

You will see that the dots begin to form a regular curve, but its shape is not clearly marked in the earlier stages. By the time the number of questions is as many as five (Pl. XXXIX.) the curve is not unlike the curves that are produced by many examiners who set good questions and are engaged in marking candidates who are quite conscientious. The remarkable thing, then, is that it is possible for an examiner setting a few infinitely difficult questions to infinitely unconscientious candidates to obtain a curve which will not condemn him out of hand.

I wish, however, to show you the curves that he would obtain if he set ten or twenty such questions. You will notice how the likeness to a gendarme's hat disappears, and how much more like a steeple the curve becomes. It may safely be said that the form of curve we are reaching is one that should be shown by no good examiner's results.

If the number of questions were infinite, the curious result is obtained that the two portions of the curve merge in the base line and in the middle vertical line, while the area enclosed retains a finite value. In fact, according to the doctrine of probabilities, all but an infinitesimal percentage of candidates must answer half the questions right and half wrong, since they

know nothing about any of them, and have simply to say "Yes" or "No" at random.

I may, perhaps, point out that it is not necessary to assume that the questions are all infinitely difficult in this part of our investigation. I have done so in order to preserve the conception, which is essential to my treatment of the subject, that the candidates are of all degrees of ability. But I may still retain this idea, and yet suppose the questions to be of finite difficulty, if I make an assumption, which, for the sake of my own safety, I hasten to add, is purely hypothetical — that examiners are infinitely foolish. That is to say, we are to suppose that they set questions which candidates can answer more or less rightly from their own knowledge; but we are further to suppose that the examiners themselves do not know whether the answer is right or wrong, and give their award of full marks or nothing at random. The type of curve would then be obviously the same as that which we have just considered.

Now, though this supposition is absurd, I should like to warn young examiners in passing against the temptation of setting questions for effect (i.e., to produce a brilliant examination paper which they can hand round to their friends) without any clear conception of what they would be prepared to accept as a sufficient answer. To defeat this we used often to ask examiners for full solutions to their own questions.

There continued to be a tradition in my time at Cambridge that, in the year in which Lord Kelvin was second wrangler, several of the questions in the Mathematical Tripos referred to vast and difficult problems, the solution of which he had communicated, while still an undergraduate, to the Royal Society. He was tempted to treat these at great length, and with all the newer developments which had occurred to him since. His more agile competitor for the position of Senior Wrangler had assimilated the bare results, as published in the Transactions of that Society, and, putting them down in a brief form, obtained a longer time for the other questions, and so secured the coveted position.

#### CURVES CHARACTERISTIC OF VARIOUS EXAMINERS AND SUBJECTS.

Now that you are somewhat accustomed to the consideration of examiners' results in connection with a diagram, I will introduce you to various types of curves characteristic of different examiners and subjects. It is at this point that I most regret the absence of the hundreds of curves which I have at home, as I am sure that we should all enjoy discussing actual rather than hypothetical results. However, my eye has so long been accustomed to the forms of these curves that their general features may be relied upon.

One of the simplest cases to consider is an examination in English Composition. As a rule the examiner reads through the candidate's work, noting incidentally mistakes in grammar

or orthography, but not penalising by separate marks each error of this kind. At the end of his perusal he tries by a single effort of mind to assign a mark to the candidate's work, taking into consideration, in that effort, both matter and style. When the curve is plotted out, it usually takes forms such as these (Pl. XL.). The better the examiner, the more dome-like the top, and the worse the examiner, the more pointed. You will observe how closely this curve resembles certain stages of the one that we have already considered, but for the present I do not wish to dwell upon that similarity.

In handwriting the examiner has to consider the clear formation of each letter of the alphabet, and a number of other points to which I need not now allude; but, as in the subject just considered, he has, at the last, to determine the candidate's marks by a single effort of mind. Accordingly, you will not be surprised to hear that the form of the curve closely resembles that for English Composition, the best examiners spreading the candidates furthest apart.

In both these subjects, namely English Composition and Handwriting, it has been found by experience that the marks of two examiners are needed in order to produce a satisfactory result. The curve representing the mean of two examiners is shown on the diagram.

Let us take next a Dictation paper. Suppose, for the sake of simplicity, that, without considering minor defects, the examiner makes a certain deduction for each mistake in spelling. The form of curve in this case (Pl. XLI.) is startlingly unlike that which precedes it.

To complete the elementary subjects, I will now show you curves in Arithmetic. The first (Pl. XLII.) which I place before you, refers to what is known as a "Test" Arithmetic: that is, a large number of easy questions which require a knowledge of the usual rules, and accuracy and rapidity of calculation, but which do not tax the reasoning powers to any considerable extent.

In all competitive examinations of any importance a Higher Arithmetic paper is also set. This paper is often "stiff," requiring ingenuity of mind, and a sound grasp of the principles of Arithmetic rather than accurate or rapid calculation, for its solution. The general form of the curve is that which I now show (Pl. XLII.).

Freehand Drawing also, in the hands of some examiners, is represented by curves of special shape. As a general rule the form in this subject approximates to the form of the curve for English Composition or Handwriting, since the value of the drawing has to be ascertained by a single effort of judgment. But I have known an instance in which the curve merged into a horizontal straight line across the paper. It is interesting to notice that this result was arrived at by a reaction from the tendency to group candidates too closely. The examiner



in question, being aware how difficult it was to separate his candidates, adopted the course of spreading out the drawings on a very large table, and continually shifting their position until he had obtained what he considered their proper order of merit, when he gathered them up in order. If there were 100 papers, he then assigned one mark to the lowest in the bundle and 100 to the highest. It is thus clear that he placed ten candidates upon each ordinate.

The other instance I shall give is that of Geometrical Drawing. You will see that the candidates are well spread out and that the curve is much closer to the form of a gendarme's hat than any I have yet shown you. It may be of interest to you to know that Professor Hele-Shaw, who is at present doing such admirable work for the Transvaal Technical Institute, used to act occasionally as an examiner under the Civil Service Commissioners in this subject, and that his curves invariably tended to assume the form before you.

RESEMBLANCE OF CURVE OBTAINED BY BEST EXAMINERS TO  
CURVE OF PROBABILITIES.

You have now seen a sufficient number of curves of different shapes to make you understand the difficulties that presented themselves to me as soon as I began to "plot" the results of examiners from their mark sheets. Until this had been done it was impossible to analyse the character of the marking, even after hours of study of the mark sheets themselves. But as soon as the graphical representation had been arrived at, the whole matter was simplified. It was only necessary to determine whether there was any special form of curve, to which the many varieties that have been placed before you ought to tend, or whether each subject, and even each examiner, might be properly represented by a different curve.

I very soon became convinced that there was a tendency among the best examiners in many subjects to obtain results which gave the graphical form that I have shown you last, namely, the gendarme's hat.

This form is one which is recognised by mathematicians as belonging to the so-called Curve of "Errors." I can best illustrate what is meant by this curve by supposing that some person in this room, experienced in the use of fire-arms, were asked to fire shots at a paper target on which a vertical straight line had been drawn as the mark to be aimed at. After a large number of shots had been fired, you would find that the holes in the target were arranged in about equal numbers on either side of the line, and that very few had actually hit the mark. If the distance of each shot from the centre line were measured and entered on a table, we should find so many falling within one inch of the line, so many between one inch and two inches, and so on. The curves now placed before you (Pl. XLIII.) are produced by showing the number of shots falling

within one inch on one side as an area bounded by itself and the base-line at top and bottom, and by the centre line, and ordinate erected one inch from that line, as sides. Similarly the area, showing the number between one and two inches, has sides bounded by the ordinates at one and two inches from the centre line, and so on.

Now I show you a second curve, in which the pistol has been put into the hands of an inexperienced person. You will at once perceive that these two curves are familiar to you. The curve of the good shot resembles the curve of the bad examiner, and the curve of the bad shot the curve of the good examiner. I think you will spare me giving you the mathematical equation of this curve, although many of the theorems and problems connected with it are extremely interesting. In preparing my paper to-day I have had to consider some of these questions from a mathematical point of view, and in doing so I have had the inestimable advantage of the assistance of Miss Fawcett. I do not, however, propose to weary you with the mathematical treatment of the subject; but one result deserves consideration, because it is at the root of all the properties of this curve. If we allow the two sets of shots to be fired at one target, and classify them as before (dividing each total by two, since the number of shots is doubled), we shall obtain a curve of the same family as the component curves. However, many times the process is repeated, each marksman will obtain his identical curve—on the supposition that he does not improve owing to practice—and of course the resultant curve due to both sets will be repeated also.

Instead of taking only two performers with the pistol of unequal merit, we may bring within our view a considerable number, in an ascending or descending scale of accuracy, and trace upon one sheet a series of these curves.

In each of these curves it should be noticed that the extreme portions never touch the base line, but they approach closer and closer to that line, so that the area enclosed in any case between it and the curve in question depends practically upon a portion on each side of the middle ordinate, which is at a measurable distance from that ordinate. Where the practice is accurate, the portion of the whole figure that may be safely excluded in calculating the area is much larger than in the cases where the shooting is wild.

A measure of the accuracy of the marksmen is obtained by drawing an ordinate to divide into equal parts the half area to the right or left of the middle ordinate, and estimating the distance between these two ordinates.

The whole area under consideration represents the total number of shots, and is therefore the same in the case of each curve. For the sake of simplicity we may suppose that 100 shots are fired. It is not true that that number of shots will in any



case give the exact curve. We should only obtain its precise form by firing an infinite number of shots and then reducing the whole to a percentage. But for the sake of simplicity in our argument we will talk of 100 shots as the number that has been fired, and say that the area is proportional to that number. We see, then, that all the areas enclosed by each of these curves respectively and the base line are equal. And this gives us a way of plotting any one of the series if a single curve has been drawn. It is only necessary to suppose the curve to be stretched to a certain extent in either the horizontal or vertical direction and to be contracted to a proportionate extent in the other direction, in order to pass to another curve of the series. In fact, if one of the curves were painted on a stretched india-rubber sheet, all the other curves could be got from it by pulling the sheet in one direction and slacking it off in the other.

Another plan would be to bend a loop of wire into the form of one of the curves, and to place a lamp behind it so as to throw the shadow upon a screen. The loop and lamp might easily be made to move in such a manner that the shadows in the successive positions gave the whole series of curves.

You will notice the points which show the intersection of neighbouring curves with one another. These produce, if joined, what is called, in mathematical language, the envelope of the family of curves. In this case it is a rectangular hyperbole.

#### CANDIDATES DISTRIBUTED ABOUT MEAN CANDIDATES ACCORDING TO LAW OF PROBABILITIES.

Now, instead of our performers with the pistol, let us take the case of a series of examiners. As soon as I had observed that the curves of good examiners tended to approximate to the curve of errors, I cast about for the reason of this similarity. It is not far to seek. If we consider one particular candidate as the mean candidate, that is a candidate such that there are as many above him as below him, we shall see how natural it is that the candidates should group themselves about this central figure as the pistol shots about the mean shot. It is clear that the curve of the good examiner should resemble the curve of the bad shot. The object of examination is to separate the candidates from one another as widely as is permissible under the given conditions, while the object of the target-practice is to get as many shots near the central line as possible.

And here we come to a most important limitation. You have already noticed that the curves we have been considering never touch the base line, that is to say that, given a sufficient number of candidates, there will always be one or two removed to an extraordinary degree from the bulk of their fellows. But the examiner is obliged to give marks within certain limits,

which he fixes arbitrarily as 0 and 100. If he were to place his zero point at a very great distance from the middle point, representing 50 marks, he would be able, no doubt, to make allowance for extraordinary candidates; on the other hand, the bulk of the candidates would be placed so close together that he would not be able to distinguish between them in any satisfactory manner. He is therefore bound to choose points such that the areas enclosed between the base line and the curve which lies beyond those points are very small compared with the areas up to the middle line. All the candidates beyond those points must be considered as having either nought or full marks.

Now you will see, I think, how an examiner in English Composition, especially if he is a University man who has become acquainted with the finest examples of literature, tends to get a very steep form of curve (Pl. XL.). He looks at some one paper, which differs to a considerable extent as regards both style and matter from the mean paper, and says "This paper should have 80 marks at least." But then he thinks, perhaps unconsciously, "How do I know that, before finishing the pile of papers before me, I shall not find a budding Milton or Addison or Charles Lamb? If I give this candidate 80 marks, shall I be able to assign its true value to a composition of such extraordinary merit?" So he only awards 60 marks to the composition, and finds almost certainly, when he come to the end of his pile, that no candidate has received any mark near 100. It is too late now to begin marking the papers all over again, and accordingly he sends in returns which do not serve to distinguish between the candidates in English Composition to the same extent as they are distinguished in Geometrical Drawing, for example. The result is that a good candidate in the former subject is treated unfairly as compared with a good candidate in the latter subject.

Again, we see why the curve (Pl. XLI.) in the case of a dictation paper is so abnormal. It is owing to the system of deductions. If 10 marks are taken off for each mistake, all candidates having more than ten errors receive no marks, whereas, if we were to assign negative marks, the curve of errors would almost certainly be reproduced, the mean ordinate being below the zero point. The divergence which you perceive near the point representing full marks is due to there being a good many candidates who make no important mistakes. If minor defects, such as refinements of punctuation, were considered, and the scale stretched beyond 100, this divergence would also disappear.

It is manifest, now, that the straight line drawn across the diagram to represent the result in freehand drawing shows that the examiner's marking was wrong. On any natural hypothesis as to the candidates' powers this could only represent the dome of the curve, and we should have to suppose

in addition an immense number of candidates who obtained more than full marks and less than zero respectively.

The curves in the two types of Arithmetic papers (Pl. XLII.) are, in the same way, only uncompleted forms of the curve of errors, and may be said to correct one another when the marks of each candidate are added to give his total in the subject. This is not, however, exactly true. If we were considering the perfect curves of error which only differed owing to the displacement of the whole figure in one direction or the other about the middle vertical line, the combined curve would still belong to the same family. But each of these curves becomes truncated and disfigured either at the right- or left-hand bounding ordinate. I cannot pursue this question further, but it may introduce important limitations in regard to the perfect accuracy of the method.

Finally, I return to the first form of all (Pl. XXXVIII.) which I showed you--the form, you will remember, of the examiner who was anxious to do more than justice to his lady examinees. Its two horns would suggest, in the case of a pistol shot, that the marksman had aimed alternately at each of two vertical lines. May not the explanation in this case be that the examiner forgot during certain periods of his work that he was marking the handwriting of women, and treated the papers then examined as severely as he would have treated men's papers? Then, remembering the fair candidates with which he was dealing, may he not, at other periods, have taken a mean standard of writing of a lower kind, such as he considered appropriate to the sex?

#### APPLICATION OF THIS SIMILARITY IN FORM OF CURVE TO IMPROVEMENT OF EXAMINERS' MARKING AND PAPERS.

The problem which presented itself at this stage was how to bring these very different results into some accord. In order to give equal weight to various subjects having the same maximum, it seemed to me necessary that the examiners should have a common standard to work up to. Accordingly, during the latter period of my connection with the Civil Service Commission, I caused such a diagram as has been placed before you to be printed on the sheet containing the examiner's report of his work. On that diagram, also, was printed a curve such as the one I am now indicating, resembling a moderate-sized gendarme's hat. If, as often happened, the examiner had 1,000 papers to mark, he was requested to go through a batch of 100, taken at hazard, and to plot his curve upon the diagram. After a few examinations an old hand would probably find that his curve for the first 100 resembled closely the standard curve before him, but a fresh examiner might find himself altogether beside the mark. In such a case he was asked to put aside the first 100 papers and to begin marking the fresh papers on such different lines as would, in his judgment, produce an approximation to the normal curve.

On the supposition that he had achieved that result for the second 100, and continued to find that his curve was pretty constant for the third 100, fourth 100 and so on, he was asked at the end of all the papers to re-mark the first 100.

You might imagine that many examiners disliked having to place themselves upon this bed of Procrustes, but in the generality of cases it was not so. They positively took a delight in examining themselves. The process became one of self-education in marking.

Before leaving this part of my subject I should like to warn you that certain causes, which an examiner cannot always control, may make it difficult to obtain such an ideal curve as I have shown. It is not possible for me to enter fully into this part of the subject, but I will point out one cause at least that he can control—I mean the examination paper.

Good marking will not compensate for a bad paper. Every candidate must have his chance, in some question or other. Otherwise the examination is like a hurdle race in which the hurdles are so high that a considerable number of candidates find themselves stopped from reaching the goal at all.

The curve, in such a case, tends to assume a shape of this kind, mounting very rapidly to the zero line (Pl. XLI.)—just the curve, in fact, which we have already seen in connection with a dictation paper. In this instance it is not the marking which is wrong, but the examination paper.

Accordingly, I found in practice that it was necessary to point out to examiners, before ever their papers were proposed in manuscript, that they ought to divide the questions roughly into (say) three portions, of which one portion could be answered by candidates of inferior power, a second should be within the range of mediocre candidates, and a third only possible to candidates who might be classed as good to excellent. The result of these directions was that examiners soon found little difficulty in spreading out their candidates in the desired way. In setting their questions they had before their eyes the little gendarme's hat.

Among the causes, beyond the control of the examiner, which may interfere with the formation of his curve, we must reckon as in the first rank: (1) such a small number of candidates as does not give fair play to the law of probabilities; (2) any selection of candidates by a preliminary examination or other means.

With regard to the causes just named, I will only say that it has been found that the method can be applied successfully when there are not less than one hundred candidates, and that, even below that number, the curve, though irregular in formation, gives us very useful information as to an examiner's capacities. With regard to the second cause, a great deal can be done to produce a satisfactory curve by setting such questions

in the further papers as are only addressed to the candidates who remain after the preliminary sifting.

APPLICATION OF THE CURVE OF PROBABILITIES OUTSIDE THE  
EXAMINATION ROOM.

I trust that I have now fulfilled the promise with which I started, namely, to show you how examiners themselves may be examined. And not only this, but you will understand that it is possible to educate examiners so as to enable them to form a much more accurate and sustained judgment of candidates than would have been within their power without such preliminary guidance.

By dwelling so much upon this particular application of the curve of probabilities, I trust that I have not altogether diverted your attention from the more general aspects of its usefulness. We are most of us very bad examiners of the phenomena that comes before us; bad judges of people, and bad judges of events. Any method that will enable us to find out our own deficiencies in these respects and to correct them cannot but be of the greatest assistance.

Who does not know the would-be critic of human nature who is almost unable to distinguish between moral qualities, and in whose eyes actions are neither black nor white, but of an almost indistinguishable grey? Such an examiner of character would assign marks ranging between (say) 40 and 60 to all persons with whom he had to deal, and his curve would be of that steeple-like formation which we have learned to distrust.

Or again, there is the man who judges strongly of particular deeds, but does not admit into his view a sufficient number to accurately gauge the character of the person under scrutiny. He resembles the bad examiner who sets a single question, to which "Yes" or "No" is the only reply, and, in dealing with the unconscientious people of this world, he is liable to make the gravest errors. With him everyone is at one end of the scale, or the other, and receives no marks or one hundred.

If some of you who are present here to-day would take the trouble to mark the persons with whom you come into contact in such a manner as I have indicated, the process might reveal to you strange aberrations in your judgment as soon as you began to reduce your estimated marks to a curve. May I suggest that such mark sheets, indicating the moral value of your acquaintances, should be destroyed at once, or that the candidates should be known, as in Civil Service examinations, by numbers alone?

And the difference between people is not less profound in their estimate of the importance of events. There are those who think that every occurrence is the crisis of their lives, who gather themselves up to clear the obstacle and who pant after it is past. There are others who go through life without realising that they have had a share in any important event at all; who

have achieved or who have missed great opportunities, and who will tell you that such and such a combination of circumstances was not in the least extraordinary, and that their own action at the time did not present any points of interest. If we could step out of our lives, as it were, for a short time, and give marks to the events that have happened in them, I believe, again, that we should get a knowledge of our own weaknesses of judgment that would be of inestimable service to us in the future.

The faculty in the human mind that seems most concerned with the estimation of probabilities is common-sense. It is, I believe, the quality which enables us to arrange people and their actions, and the events that concern us and other people, according to the ideal curve that I have shown you. I can certainly say this, that, in choosing examiners in the narrower sense, the first quality that I look out for is not profundity of scholarship or brilliancy of imagination, but common-sense. In its higher manifestations this quality is as unusual as any other of the great gifts of the mind, but we can, by education, do much to cultivate it, and if I have suggested to you to-day a means by which that end can be accomplished, I shall have done much more than enable you to retaliate on an unfortunate set of beings, who are no more likely to misjudge you in the examination room than others are to misjudge you in the world at large.

#### EXPLANATION OF PLATES XXXVIII.—XLIII.

PLATE XXXVIII.—Wrong distribution of marks.

PLATE XXXIX.—“ Yes ” and “ No ” curves.

PLATE XL.—English composition curves.

PLATE XLI.—Curve for dictation.

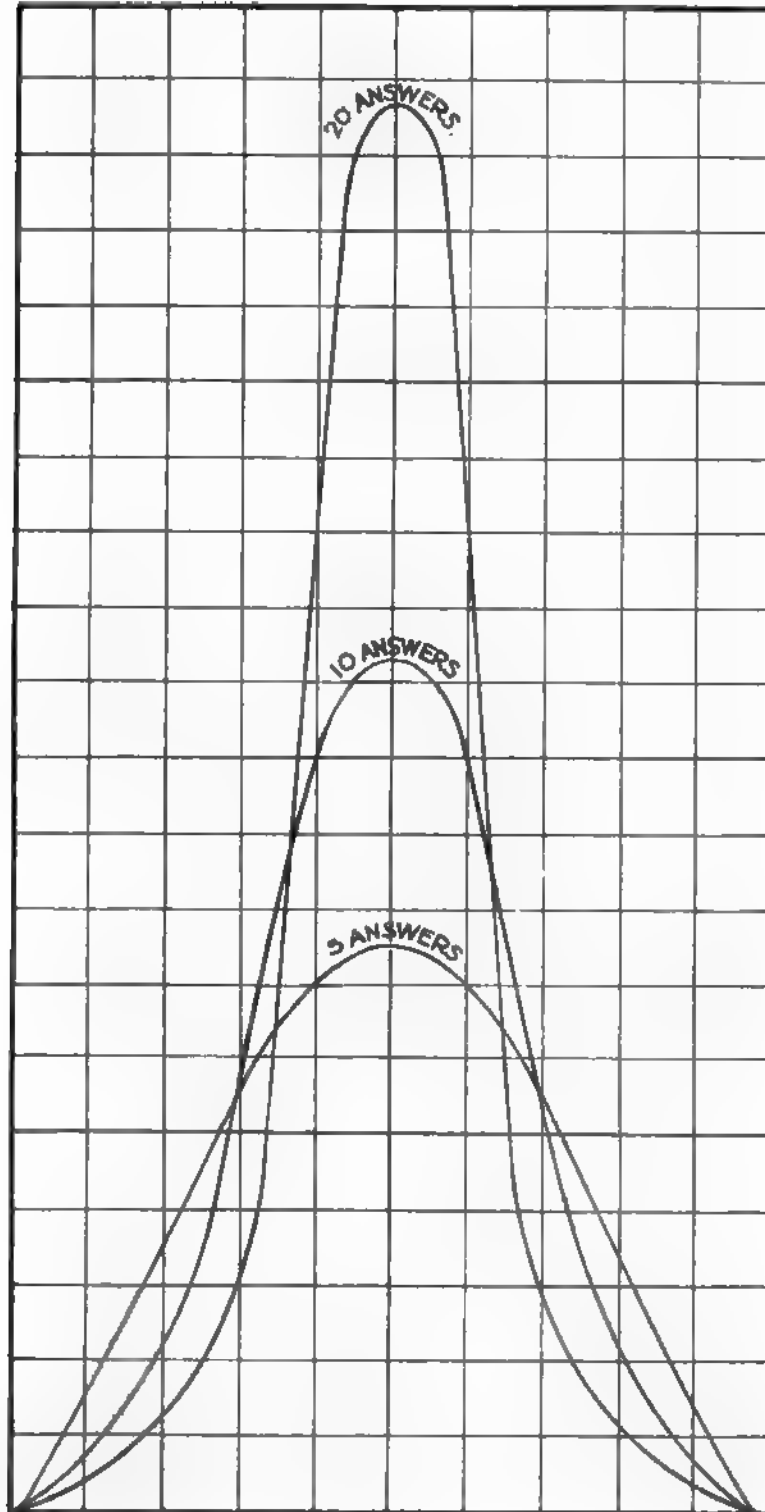
PLATE XLII.—Arithmetic curves.

PLATE XLIII.—Curves showing pistol practice.



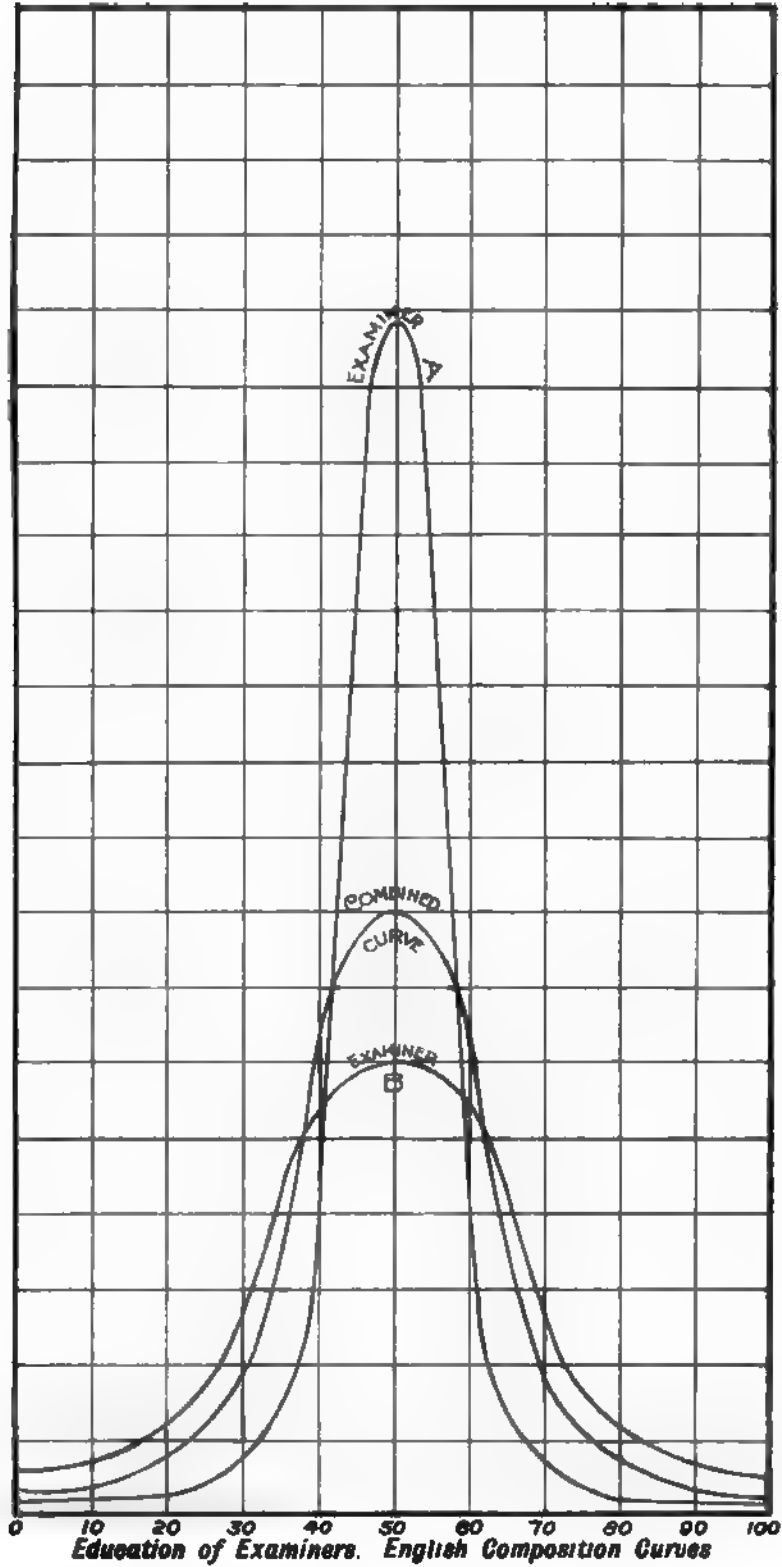






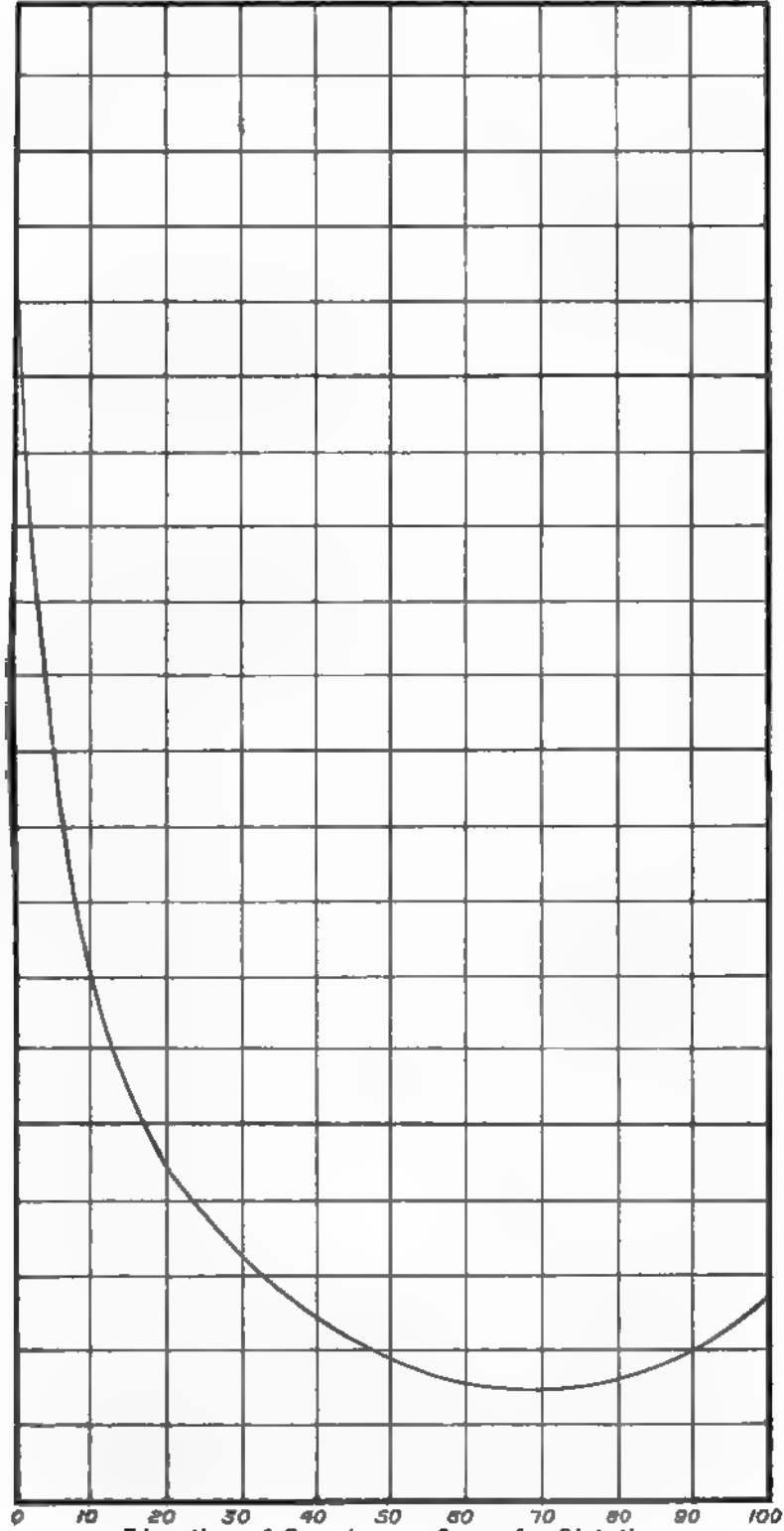
*Education of Examiners. "Yes" and "No" Curves*  
*E. B. Sargent:*





E. B. Sargant:

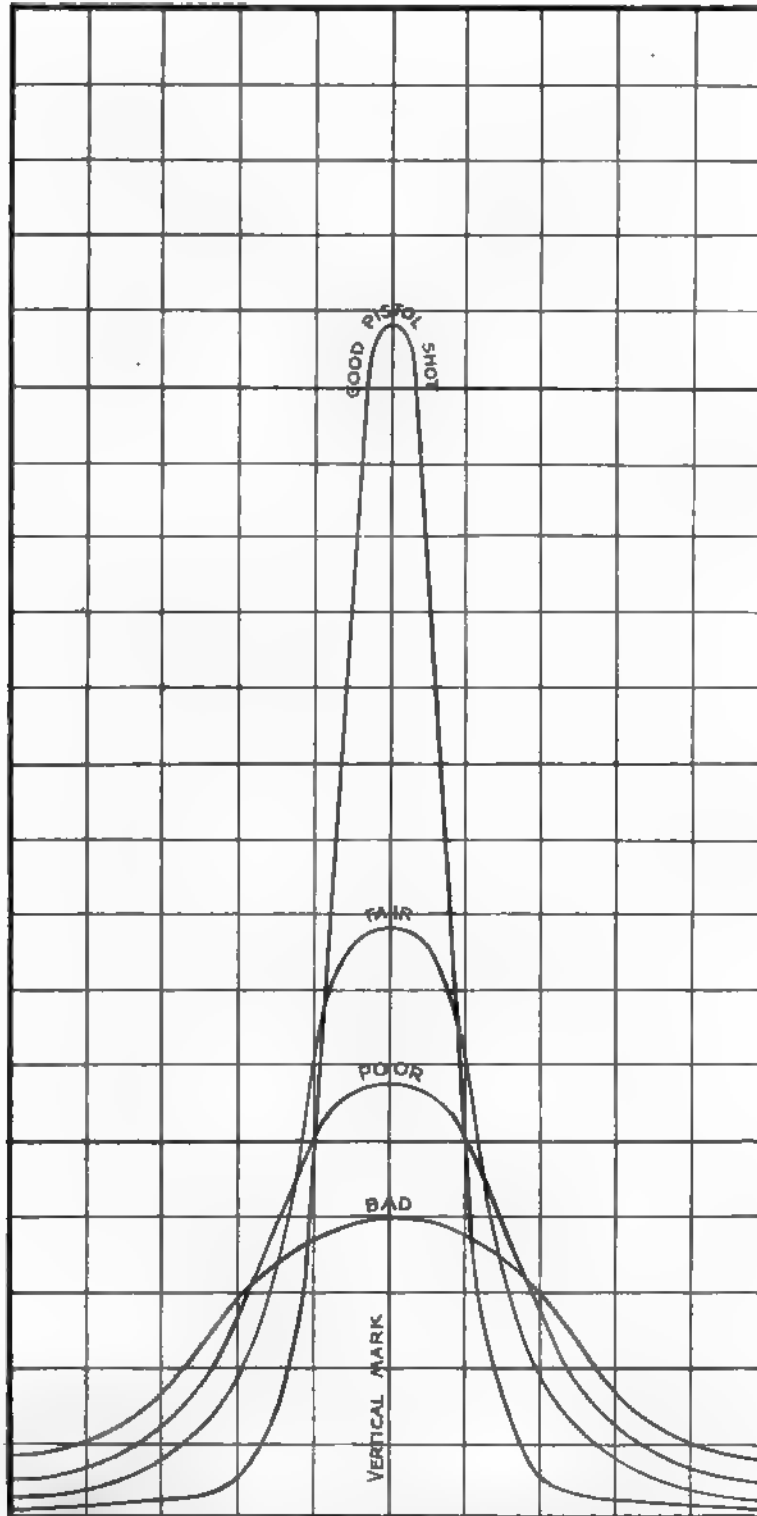




*Education of Examiners. Curve for Dictation.*

*E. B. Sargent:*



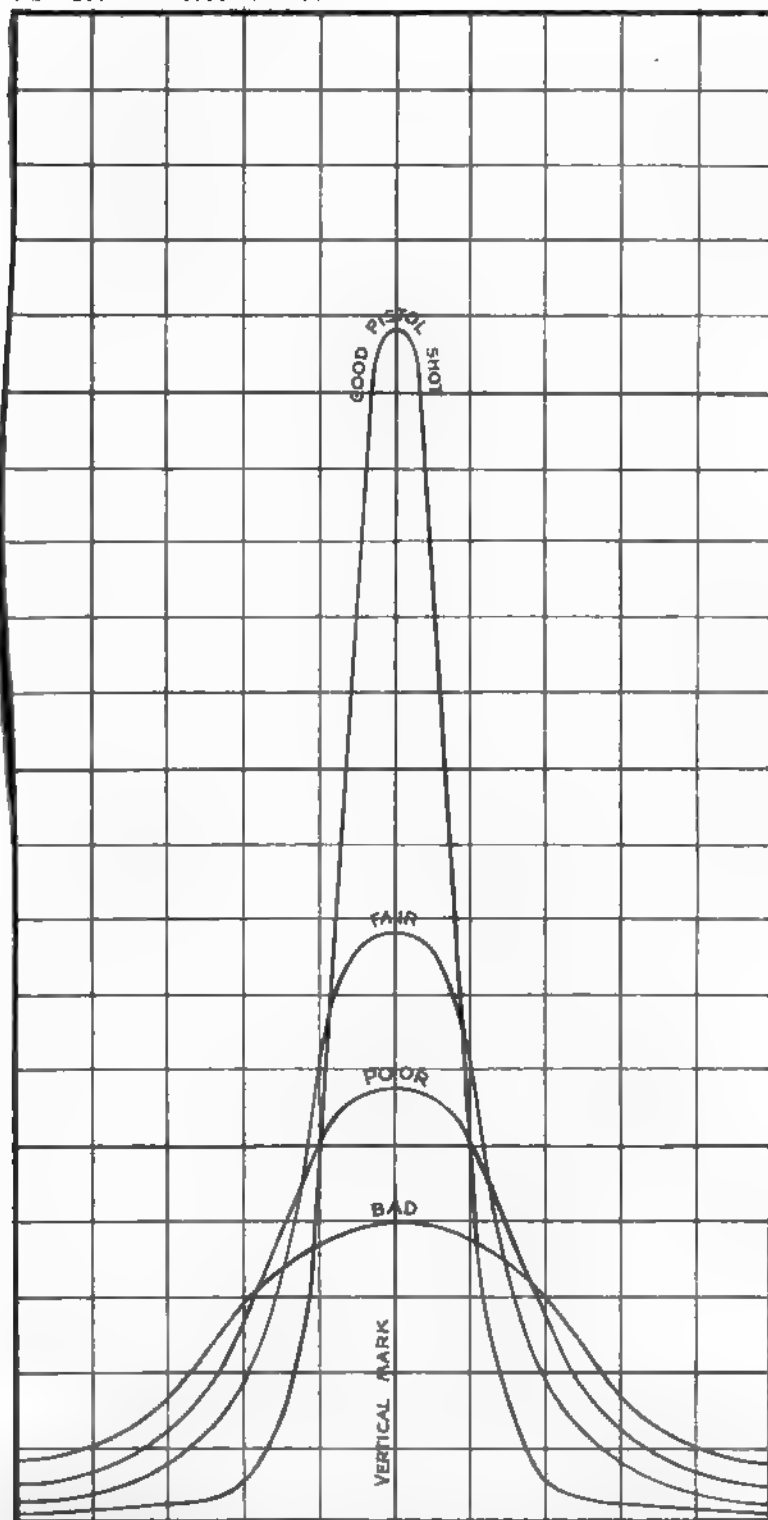


*Education of Examiners Curves Showing Pistol Practice.*

*E. B. Sargent:*







*Education of Examiners Curves Showing Pistol Practice.*

**E. B. Sargent:**

which he has certainly never seen before, and which he is not likely to see again except in the laboratory.

And so it is with most of the other types on which he works; they are provided for him out of a bottle, or brought to him by the laboratory attendant, and he never has an opportunity of seeing any of them in their natural conditions and environment. They are either preserved or stained or cut into sections and mounted for microscopic examination.

It is not, however, that I wish to condemn the type system of teaching biology altogether. It has many admirable points; it is definite, systematic, and an excellent school to accuracy of observation, as well as training the hand in neatness, and when the course is finished the student should have obtained a very good grasp of the evolution of the animal and vegetable kingdom through all its various modifications and complexities; but I should like to see superadded to the strict laboratory work a certain amount of nature study, which though less definite and doubtless more difficult to teach, would tend to develop in the pupil a love of nature and out-door study.

This is what the modern morphologist lacks as a rule. Unless an animal has some bearing on an evolutionary or morphological problem, he takes but little interest in it.

My special interest in the subject of nature study is, I fear, not altogether unselfish. I am not so much thinking of the training of the pupil as of the results which may be achieved in a country like South Africa.

In preparing my series of hand-books on the fauna of South Africa I have been very much struck by the lack of knowledge and of recorded observations in regard to the mammals and birds of South Africa, and it is my hope that if some sort of course of nature study were introduced into South African schools there would be trained up a certain number of men and women who would not only become lovers of nature and natural things, but would be able and willing to exercise their observational powers and to further our scanty knowledge of the living creatures around us. Even the observations of school children themselves might be of great interest and value if accurately recorded by teachers and others.

This is not the place, perhaps, to lay down a full and complete programme or course of nature study for schools, but some indication may be given of the lines on which school children may be trained.

In the case of birds a great deal could be added to our knowledge of migration, which is now exceedingly incomplete, by noting the dates of arrival and departure of various birds in different parts of Africa. It is a well-known fact that the common English swallow (*Hirundo rustica*) leaves Europe in September and migrates south to Africa, so that during our summer months from October to March this bird is with us here in the Southern Hemisphere. We know, however, very little

About the distribution of the bird in South Africa; there are specimens in the South African Museum from the neighbourhood of Cape Town, obtained between November and March, and we have recently one from Irene, in the Transvaal, shot in November, while the late Mr. Seebohm observed that the swallows do not leave Natal till April; beyond these few facts we know very little about the times of arrival and departure of this comparatively common bird. Again, hitherto no very definite evidence is forthcoming that the European swallow nests in South Africa; Mr. Charles Andersson states that "in some uncivilised parts of Africa these swallows affix their nests to some projection of a rock or trunk of a tree or occupy cavities in rocks or banks," but no other naturalist has yet confirmed this statement, and I think it is probable that Mr. Andersson was confusing the white-throated swallow (*Hirundo albigularis*) with the European species when making this statement.

The white-throated swallow arrives and departs with the European swallow, but never goes as far north as Europe, in fact its resorts in winter from March to September are unknown, though doubtless somewhere in Central Africa. During its stay here, however, it breeds, building a nest under the arch of a bridge or below a ledge of rock.

The white-throated swallow closely resembles the European bird, but is easily distinguished by the colour of its chin and the throat, which is white instead of chestnut.

Here are the samples of questions to be answered by observations carried out on nature study lines, and which require no special scientific knowledge for their solution, only patience and accuracy.

There are many other similar problems in South African ornithology awaiting solution, and the instance mentioned is only to be taken as a sample.

In regard to mammals again, the same paucity of information exists. We know a little about some of the larger antelopes through the observations of sportsmen, but we are quite in the dark about the smaller fry, such as bats, field-rats, shrews, and moles; in England and the colder countries, bats and many other small animals, as is well known, hibernate during the cold weather, remaining in a torpid condition until the returning spring warms them into life again. Are such animals active throughout the year in South Africa, or do they go into retirement during some seasons? In some countries where the summers are hot and dry aestivation or a summer dormant period prevails, but we do not know whether such is the case in South Africa or not.

Another very interesting line of inquiry and observation is with regard to the life history of the frogs and toads in South Africa. Very little has been done in this matter, and it is a subject full of interest and importance. The modification of the ordinary tadpole stage and of the various contrivances by

means of which the eggs or tadpoles are protected or cared for during the most critical period of their existence form a most entrancing chapter of natural history; all of which, as far as South Africa is concerned, is an absolutely untrodden field. Again, patience and accurate observation are all that are necessary to the unfolding of these mysteries.

Among the lower animals I need hardly say that there is a wide scope of observation open for anyone who feels inclined to occupy himself in this way. The social habits as exemplified by the wasps and bees, the ants, and the white ants or termites, the mimicry habits of various insects which resemble their surroundings, or other forms specially protected by nauseous taste, or special weapons of defence, the architectural habits of spiders and of many insects—all these offer ample fields for research.

There can be no doubt that the encouraging of the collecting habit which is so strongly ingrained in many people is of great help and stimulus to observation, although if carried too far it sometimes tends to mere acquisitiveness without any curiosity or interest in the objects collected; pupils should therefore be encouraged to collect systematically objects of natural history, but care should be taken that in all cases notes, and if possible rough drawings, should be made to accompany these, and everything should be carefully labelled with all the particulars of capture, such as date and locality, and it should be clearly impressed on pupils that the object of making collections is not the mere accumulation of often useless specimens, but to obtain a few carefully selected objects for subsequent reference and study.

Perhaps the formation of a small school museum is preferable to the encouragement of individual collecting, as in this case the selection or rejection of specimens rests with the teacher, and the accumulation of mere lumber can be checked.

I should like to recommend to anyone who proposes to take up the teaching of this subject a little book recently published by Mr. Ernest Stenhouse, entitled "An Introduction to Nature Study." It consists of a series of lessons, each consisting of two parts. First, precise instructions for practical observations and experiments designed to encourage the reasoning faculties of the students; secondly, a descriptive portion, in which the meaning and relation of the results obtained are discussed: at the end of each chapter are a number of additional exercises, either original or taken from examination papers.

The book is, of course, prepared for English schools, and all the examples are taken from the animals and plants commonly found in England, but I do not think there would be much difficulty in adapting a good deal of the matter for South African schools. The first half of the book deals with plant life, which I have not said anything about here, as my

studies have been purely Zoological, but which certainly should form at least half the lessons in a course of nature study. The second half of the book deals with animals, commencing with the rabbit and passing downwards in the scale to the crayfish and earthworm. Finally, the volume closes with a chapter containing an outline of a monthly nature calendar, indicating the principal animals and plants to be noticed each month in the year.

## 41.—THE HANDLING OF YOUNG CHILDREN.

By P. A. BARNETT.

When one approaches the question of the handling of young children, the first thing that strikes one is the assurance with which people deliver themselves of opinions. There is only one other topic, in this country at all events, on which folk speak with equal assurance, and that is on the handling of "natives." In both cases people presume on their scant knowledge of human nature; in both cases there is shown, with lamentable persistence, a lack of principle to start from, and of any large or disinterested view of the ends to be attained. The most "experienced" people sometimes betray the most amazing ignorance.

It is a little difficult to say—or to see—what constitutes an "expert" in either area. You may deal with children, and you may employ natives, to the end of time; and you may yet be unable to make the best of them, or even to turn them to your own best profit.

As to your opinions about children and their upbringing, a conspicuous public or official position is no guarantee of sense and sobriety. Some of the most foolish and irresponsible chatter disseminated in the English world of late has come from eminent persons; and some of the most cruel and unwarrantable denunciations of teaching and teachers, too. It is not at all uncommon for folk who have occupied high places in which, if they had been honest and intelligent, they could have mended glaring defects in educational machinery and practice; who have boggled at their work for want of sense and science; to turn round on the chaos which they have increased, and declare that the whole thing is vanity, and that what is wanted is more chaos.

I do not desire for my part to pose as an expert; but I have been asked to deal as practically as possible with the business of handling young children. The only grounds on which I can expect a hearing are that I have seen many experiments, have had some experience and made some experiments myself, and have watched all sorts of educators and education-mongers, good, bad, and indifferent, for many years.

This is an association for the advancement of science, but I hope I shall not have betrayed the Education Section when I say that I do not know whether there is a "science" of Education at all. I know of several splendid endeavours to place education on a scientific basis; but none of them seems to me to allow for the constantly changing bases of the sciences on which they are presumably built—metaphysics, ethics, psychology, physiology, or the compendious sociology.

What, however, is abundantly clear is this: that, for the practical purposes of the working educator, a multitude of applicable facts is constantly being supplied by the sciences most deeply "immersed in matter"; by physiology, especially psycho-physiology, by sociology, by ethics; and in that order, or something like it, of particularity. That is, the good educator must remember that he deals primarily with the body; then with the body and mind interacting; then with the body and mind as affected by historical and social environment; and finally with body and mind, so constituted, directed to an ethical end.

When I look at my child, I say to myself: "You must first of all be fed well, kept clean, and must develop healthy tissues; then, your intelligence shall, if I can secure it, grow pace for pace with your physical capacity, since I know that these things are inter-dependent; next, your intelligence and bodily health germinate in, and are conditioned by, and must therefore learn to operate in, this particular environment, determined by history and social conditions; finally, you are not only to be a healthy and intelligent animal, but are to live nobly, to be better than I am, to do more for the glory of God.

What is true of the single child is, of course, true also, in these large respects, of children in troops or classes. But the very first duty of the teacher or educator facing his task is to note that each child has his own history; is not in all respects the same as any other child; must be separately considered.

Here emerges what seems to be Rule I. in the handling of young children. Do not force on every child the same discipline. I do not, of course, mean that single children or classes, if you have classes, are not to follow a routine, "taking," as the cant goes, "the same subjects"; I mean that you must be prepared to treat one child differently from another. From one you may expect more than from another. Tommy will shrink and wither under a rebuke of which Polly takes no account. Polly may become bewildered without loss of virtue at a simple task which Tommy will accomplish while he is criminally cracking a nut. Jacobus will tell you a fib in all guilelessness, and merely as a work of art meant to evoke interest, which to Jacoba, who has been less fortunate in her training, would smell of the bottomless pit. A simpler illustration still: Tommy will work best with his hands on the table, while Polly—a rarer case to be sure—faces her difficulties more easily with hands locked behind her; Jacobus likes his fat legs apart, while Jacoba loses nothing in mental concentration by being made to keep her heels together. The practical moral for teachers is to enforce a pose on little children only rarely;

and then only for a very short spell, in order to drill or "pull them together." There is no unholier sight in earth, heaven, or education than a large class of little children kept quiet as stones for more than five minutes. *Mute*, you may make them, mute as mice, for a longer period; but it is easy to prolong the silence until it becomes unnerving and unhealthy. Children's chattering is not always mere ebullience. It is positively a necessary physical exercise, and is properly regulated in them by encouraging their intelligent questions and by giving them plenty of singing. In an excellent school for older girls which I once visited officially I found that five minutes of every sixty were given to promiscuous conversation; a very sensible way of letting off steam.

We have been accustomed, I fear, to test order too often by silence and by uniformity of pose. Such silence and such uniformity are useful, as other externally imposed constraint is useful, by way of drill; but mental, and, it may be added, moral activity in classes as in individuals implies much more variety of *muscular* expression than the over-anxious teacher is prepared to admit.

I noticed once a pitiful case of conscientious stupidity on the part of a teacher. Some seven-year-olds were having an "object lesson" on a pear; and the hands of one little lass stole up and sketched the pear that was being exhibited. She was pounced upon, told that she was a naughty girl, and the sketch consigned with ignominy to fire, in order that all traces of a crime might be obliterated. The instinct of the child was right, and the energetic protest of the teacher was wrong. Provision should have been made for sketching the pear, as an integral part of the lesson. An intellectual or moral operation in young children, if in no other class of people, is clinched only by physical expression.

It all comes in the end to this: that we must use machinery in such a way that, without complicating and confusing class routine, every child may enjoy the freedom needed for him to express what is in him. The unintelligent use of the orthodox Kindergarten exercises may easily end in mechanical and babyish waste of time; and especially foolish is the withholding of such instruction in the simple ancillary arts, reading and drawing and writing, as enable even a very young child to "amuse itself," as we say, without our self-satisfied interference or mental "strain."

The best thing, indeed, that we can teach children is this *how to amuse themselves*; and we cannot do it if we either laboriously and over-anxiously close to them the easy avenues of self-amusement, or painfully formalise their play and keep them perpetually under intrusive governance. A large part of



the work of the teacher of little children should consist in watching them do what they like and see what they like without getting into one another's way. Yet we rarely come across an Infant School in which the children are allowed, even as an occasional treat, to walk at their will about the schoolroom and to pore over the pictures on the walls. As a rule, indeed, the pictures in Infant Schools are hung far above the sight-line of even the gigantic teachers, and for all the good they do to the children might be in the lumber room. To have the pictures down once a year for the purpose of giving "lessons" on them makes things worse by formalising and desiccating all their associations.

Perhaps, however, the thing hardest to show to the amateur critic of education is the true nature of discipline. You may call your procedure either bringing-up, or teaching, or discipline; but you teach a child whether you will or no, and you can make profit out of his teachableness from the cradle.

The meaning of No can be understood by a baby a month old; and the youngest child can profit by the cultivation of regular habits. *Desultoriness* in the treatment of children is a deplorable cruelty. It does not promote health, originality, or freedom of development, as lazy and ill-informed people think, or affect to think; it merely binds the children in chains ultimately unbreakable, forged by their own uncombated moods and recurrent whimsies. It is a platitude, I know, to iterate that we have to teach children to govern themselves; but it must be repeated until it is believed and understood--on the one hand by the people who think that *any* constraint is bad, and on the other by those who have no other conception of education than as constraint invariably imposed from outside.

I was told to be practical, so I will be practical at the expense of being accused of carrying coals to Newcastle.

A child should be taught to control emotion first of all by controlling the *expression* of emotion; the unchecked physical expression of emotion, by reaction, increases the emotion itself. If a child cries, we have to stop its crying; not by shaking it, to relieve our own nerves; not by hitting an offending object, to relieve the child's nerves; but first by diverting its attention and even evoking its sympathy with the original cause of the emotion; and ultimately, when it can reason, by convincing it that it *can* stop if it will. All class teachers know that every now and then emotional waves sweep over a mass of little children from which they can be saved only by counter-emotion. A whole class may be unaccountably "naughty"; there is nothing for it but to rivet their attention on something new; objurgation is worse than useless.

To allow children to strike anyone in fun, even a father, or mother, or Kaffir nurse, is a form of cruelty *to the children* for which I have no adjective at command. The blow is a physical expression of malevolent emotion, which should never be allowed room for exercise. The emotion grows by what it feeds upon; and even if respect for the child's elders is restored, the instinct to hit out nervously in an emotional crisis remains. When you see in this country the too frequent and often gross incivility of young people, and of some old ones too, to their coloured dependents, the origin of the odious fault is not far to seek. The restriction of opportunity for this kind of explosion is one of the benefits of teaching young children in classes.

Cheerfulness and good humour should be fostered deliberately. No whining should be allowed; not only because a "withering" person is useless to Heaven and Earth, but because the result of uncorrected whining is an unlovely egotism. It is quite easy to train the merest articulate babe to say *T'a* cheerfully; when it grows up, to make it respect scrupulously other children's toys; and, as early as you like, to teach it to protect others. Your little boy is not playing a baby game when he walks in front of you "for fear there may be robbers"; he is putting on his uniform. And so is your little maid when she "mothers" a girl still smaller.

Rudeness or pertness should be tolerated at no period of a child's life. Some people laugh at rudeness shown by a child of two when in a child of ten it would disgust them; but there is no fixed point between two and ten at which your child naturally passes from original incivility to original politeness. A child who is never allowed to be rude to other people does not therefore feel restrained in their presence; whereas if a child is permitted to be uncivil or unkindly to parents, nurses, brothers, sisters, or servants, it certainly cannot feel at home with people who are unfamiliar with what has become its "natural manner." A good many people suffer from the lack of this discipline all through their ungainly lives; their roughness and inconsiderateness to folk who share their roof is a cause of immense unhappiness—and yet a little early training might have given their whole environment a different complexion. Rudeness is not really more natural to a little child, nor to anyone else, than kindness; but it may easily be made to flourish like a bay tree by foolish applause. Here again the class teacher has an opportunity; rudeness or pertness is an obvious public offence, and public feeling can at once be enlisted against it.

The most serious crime that any human being can commit is to kill happiness; and your children can be taught this, and should be taught it, in the interests of themselves as well as of others. If a child for a moment forgets itself, "Why," you

ask, "did you say that? You could never have meant to make A. or B. unhappy?" "One person," says Stevenson, "I have to make good -myself. My duty to my neighbour is to make him happy—if I may." Surely gaiety and urbanity should be cultivated as a duty to one's fellows. No teacher should use sarcasm as a weapon of discipline, and least of all the teacher of little children.

Here, *per contra*, is a true story which should make your flesh creep. A mother received a complaint from her little girl of five that other children would not play with her. What should the mother have done? I suggest that she should have asked *Why*. If she had, she would have found material in the case for a lesson to an only child on the duty of "getting on" with other children by the exercise of unselfishness, and by not demanding all the best parts in games or in anything else. But this is what she actually said: "Never mind, darling. Come and I will read to you. Presently when they *want* to play with you, you can say "No—won't." Could the woman have contrived a more certain device for securing the future misery of that wretched child?

In the handling of young children, if the example and cultivation of kindness comes first, the cultivation of honesty comes next.

By honesty I by no means intend you to understand mere truthfulness; I include frankness also, and the scrupulous respect for other people's rights even when the other people are not at hand to enforce them; at which point honesty and kindness mingle their streams.

There are very many children who fib lightly just in order to be interesting. Such cases should not be handled harshly, even before a class. It should be sufficient to appeal to the ever-operative ideal of little ones, the desire to be grown up. The baby, you point out, is not a witness whose help is worth much, since it cannot speak; tiny children can speak, but cannot be relied upon for great accuracy. Trustworthy speech, on the other hand, is the mark of the grown-up, and it is the best proof of grown-up-ness when speech can be credited, when people can depend and act upon it. It is a disgrace, you must urge, for a child who *can* behave as a good grown-up behaves to prefer to be untrustworthy.

And so far from the narration of fictions being an incentive to lying, it is just one of the best means of prevention. If you encourage in small children the conscious making-up of tales, you provide them with a touchstone, a contrast, by which they can compare fact and unfact. A child who lacks imagination is much more likely to lie deliberately, if awkwardly, than a child who can discriminate between reality and make-believe,

and who, when engaged in make-believe, fabricates generously, openly, joyously. You should teach your children, however, not to blend fact with fiction. The blending of fact with fiction "with intent to deceive" is the only real lying. A habit of untruthfulness is so much an intellectual defect that the infliction of a positive penalty is more likely to do harm than good. Displeasure, unconcealed sorrow, the threatened loss of confidence—these alone are likely to cure it. But only in the very last resort should confidence actually be withdrawn; you must think many times before you remove the golden bridge, self-respect, by which your wanderer will most surely come home again. And public disgrace should be reserved for very critical cases that admit no other effectual alternative.

I might prolong these remarks indefinitely, but the time allotted to me has all but gone, and I have done enough, I think, to prove what seem to me the most important facts determining the up-bringing of little children, and to illustrate what would seem to be the most profitable way of dealing with them. The mischief is not that the facts are unknown, but that they are not intelligently and unselfishly faced. The basis of all we do must be the manipulation of the child's physical constitution, the checking of bad physical habit and the strengthening of good habit. We must make allowances for great variety of type, allow as much freedom as we can to individuals consistently with the maintenance of others' freedom; and we must provide children with the means and opportunity of cultivating their own powers by "*amusing themselves*." This is neither more nor less than to lead them by their own unconscious efforts to occupy themselves, rationally, of their own accord, in their own improvement.

And finally, in dealing with groups or classes of children, it should be remembered that the multitude of witnesses, the aggregation of so much individual self-consciousness, distends the scale of a teacher's operations, as a magnifying glass enlarges an object placed under it. The teacher's acts and bearing become gigantic and immensely impressive, seen on a big scale, never-to-be-forgotten.

That is why, of all people in the world, the teacher of little children must be circumspect, judicial, urbane, firm, merciful.

## 42.—SPECIAL ASSESSMENTS.

BY STEPHEN COURT, F.R. STAT. SOC.

The question of the best method of meeting the cost of constructing the many miles of roads requiring to be made in Johannesburg, and of laying sewers and storm water drains has not yet been decided, and it may perhaps be of interest to investigate the practice obtaining elsewhere of imposing special assessments to recover the expenditure involved.

A "special assessment" may be defined as a compulsory contribution, levied in proportion to the special benefits derived, to defray the cost of a specific improvement to property undertaken in the public interest.

It may be as well to say at the outset that the use of special assessments is much more general in the United States of America than elsewhere, due partly to the fact that in other countries a considerable proportion of improvements, such as street construction and sewerage, is carried out by the owners of the land, while in America such improvements are made by the municipality. Johannesburg is in the same position as the United States cities in this respect.

In England the principle was adopted as early as the 15th century, when commissions were appointed to secure the construction or repair of "walls, ditches, gutters, sewers, bridges, causeys, wears and trenches," and to apportion the work, or the expenses of the whole, upon all whose landed interests received benefit therefrom. In 1662 an Act was passed authorising the widening of certain streets in Westminster, and providing for the cost to be defrayed by voluntary subscriptions. If the subscriptions did not prove sufficient, the commissioners to lay out the streets were authorised to charge the owners of the property in proportion to the benefits received.

Five years later, in 1667, an Act was passed to regulate the rebuilding of London after the great fire, and the Corporation was empowered to appoint certain persons "to impose any reasonable tax upon all houses within the said city in proportion to the benefit they shall receive thereby, for and towards the new making . . . the said sewers and pavements."

Section 150 of the Public Health Act of 1875, allows local authorities to pave and sewer, etc., streets in default of owners and to recover the expenses of doing so according to the frontages of the premises abutting on the streets.

Section 10 of the Private Street Works Act 1892, allows the urban authority to take into consideration the greater or less degree of benefit derived by any premises from the works instead of tying them down to the foot front method of apportionment.

As regards large improvement schemes involving the acquisition and demolition of property and the opening of new thoroughfares or widening of old ones, the London County Council have been successful in obtaining parliamentary sanc-

tion to the levying of special assessments on property benefited. The London County Council first adopted the so-called "betterment" principle in November, 1889, and introduced a special assessment clause in the Strand Improvement Bill of 1890. The betterment provisions were, however, struck out by a Select Committee of the House of Commons, and the Bill was not proceeded with. The London County Council General Powers Bill of 1892, providing *inter alia* for a bridge at Cromwell Road, shared the same fate. The London Improvements Bill of 1893, providing for a new street from Holborn to the Strand and for other improvements, passed the Commons, but was defeated in the Lords Committee and was subsequently withdrawn.

A Select Committee of the House of Lords on Town Improvements (Betterment) reported in 1894 that:

"The principle of betterment, in other words, the principle that persons whose property has clearly been increased in market value by an improvement effected by local authorities, should specially contribute to the cost of the improvement, is not in itself unjust, and such persons can equitably be required to do so."

The Tower Bridge (Southern approach) Bill of 1894 became law in 1895, and authorised the levying of an improvement charge.

Subsequent London Improvement Acts authorise improvement charges in the cases of the widening of the Strand and of Tottenham Court Road, the Holborn to Strand new street and the Westminster improvement, etc.

In both Capetown and Durban the Municipalities are empowered to defray the cost of paving and sewerage new streets by means of special assessments on the owners of the land abounding or abutting on such streets.

In France the principle of special assessments has been recognised by the Legislature, but has received little application.

In Prussia a law of 1893 not only permits but directs local authorities to impose fees and special assessments in cases where the local action results in a special measurable benefit to the individual.

In Belgium the expenses of street construction are defrayed by special assessments and the principle has been extended to include the cost of constructing or enlarging footways, pavements, sewers, and also the cost of sweeping, sprinkling and repairing streets. The system seems to have been more fully developed in Belgium than in any other country in Europe.

The system of special assessments was introduced in New York at the end of the 17th century, the first law being based on the English Act of 1667 above mentioned, and has since been almost universally adopted in the United States. Its applica-



tion is wide, as may be judged from the following list:—  
 opening, laying out, grading, paving, and repaving streets—  
 street watering, lighting, and tree planting—constructing  
 drains and sewers—laying conduits and water pipes—laying  
 out and developing public parks, squares, and drives, etc. In  
 the above cases special assessments are employed to recover  
 either the whole of the cost or a part of it.

The following table shows the receipts of U.S. cities having a population over 150,000 in 1900 from the property tax, from special assessments, and in total, and will give some idea of the importance of the system as a source of revenue.\*

	Property Tax.	Special Assessments.	Total.	Population, 1900.
New York ... ..	*£14,913,054	£682,544	*£20,861,577	3,437,202
Chicago ... ..	2,859,166	649,225	5,373,548	1,698,575
Philadelphia ... ..	3,642,967	—	5,275,053	1,293,697
St. Louis ... ..	1,313,866	38,793	2,314,802	575,238
Boston ... ..	3,222,174	70,452	5,090,179	560,892
Baltimore ... ..	1,158,962	10,555	1,953,386	508,957
Cleveland ... ..	712,958	133,884	1,274,329	381,768
Buffalo ... ..	987,435	149,891	1,513,129	352,387
San Francisco ... ..	*1,254,937	—	*1,727,774	342,782
Cincinnati ... ..	771,321	—	1,397,105	325,902
Pittsburg ... ..	1,008,531	404,551	1,850,213	321,616
New Orleans ... ..	695,268	—	891,656	287,104
Detroit ... ..	734,408	92,446	1,138,131	285,704
Milwaukee ... ..	598,484	94,963	869,813	285,315
Washington ... ..	604,066	20,031	†1,567,136	278,718
Newark ... ..	627,488	74,888	1,216,141	246,070
Jersey ... ..	615,244	47,268	988,063	206,433
Louisville ... ..	545,786	15,719	751,280	204,731
Minneapolis ... ..	461,531	84,627	699,980	202,718
Providence ... ..	617,051	12,379	874,491	175,597
Indianapolis ... ..	275,803	50,235	405,076	169,164
Kansas ... ..	309,024	—	499,693	163,752
St. Paul ... ..	267,922	65,906	580,260	163,065
Rochester ... ..	498,620	167,492	867,301	162,608

\* Including State Tax.

† Including £687,455 appropriated from funds of U.S. Treasury.

We find, therefore, that special assessments are of comparatively modern development, and that their application is wider in the U.S. than elsewhere. In England and in France they have been little used. In the case of England, at all events, the fact that the streets are made by the owners of the land accounts in great measure for special assessments not being brought prominently under notice. In Prussia and in Belgium their introduction is quite recent.

Turning to the theory of special assessments, it is accepted that if the local authority incur expenditure on, say, laying

\* Compiled from figures published in the Bulletin of the U.S. Department of Labour, September, 1901.

out a new street, the result of which is to increase the value of a particular plot of land, the authority may reasonably call upon the owner of this land to defray, in whole or in part, the cost of this improvement. The owner is undoubtedly specially benefited as a result of this special outlay by the municipality, and taxation according to benefit may properly be resorted to.

The principle of contribution in the case of ordinary municipal rate is not benefit but ability to pay. In this case no particular individual is measurably and specially benefited—any benefit that he may receive comes to him incidentally as a member of the community.

The benefits of general municipal action cannot be measured quantitatively. By paying his rate the individual does not purchase from the local authority a definite amount of advantage in the same way as he may purchase some commodity at a shop. If, however, the municipality performs some special service for an individual there is no reason why the general body of ratepayers should pay for it. In fact, justice and logic both demand that the person benefited should defray the expenditure involved.

The problem of unearned increment is also to a large extent solved by the special assessment system. Dr. Rosewater, in his book on *Special Assessments*, says\* :—

“Special assessment undoubtedly transforms a certain part of the enhancement of land values from an unearned increment into an earned increment. It does this at the very time that the benefit arises, thus avoiding every taint of confiscation of vested interests. Through it may be secured the chief advantages of the appropriation of the future unearned increment, without destroying the healthful stimulus arising from the private ownership of landed property. The total increase is seldom appropriated, but only so much as is required to defray that share of the cost of the particular improvement which may represent the special benefit conferred. We have here no uncharitable begrudging of all rise in value due to conditions other than those created by the party who reaps the advantage. All that is demanded is that when a person secures an enrichment to his estate, and the expense, if not borne by him, must be borne by someone—in this instance the tax-paying public—he shall make compensation therefor. This is the true equitable principle. The contributor pays not alone because he obtains a benefit but because that benefit is joined to an expense the burden of which finds a fitter resting-place upon his shoulders than upon the shoulders of others not specially benefited.”

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\* “*Special Assessments*,” by Victor Rosewater, Ph.D., 2nd ed., New York 1898, page 144.



Prof. Seligman states† that in the U.S. the betterment principle has long been firmly rooted in the revenue system; and although there may be particular cases in which it has not worked well, the evidence of experience and the popular verdict as to the methods employed are overwhelmingly in its favour. On the Continent of Europe the system is now fast spreading because of the growing importance of municipal finance and of the more careful analysis of its underlying principles.

Special assessments, like fees, are not taxes in the ordinary or narrower sense of the term. Taxes are compulsory contributions levied to meet expenditure incurred in the interest of the community, no regard being had to special advantages which the ratepayer may receive. In special assessments, as in fees, however, the services for which expenditure is incurred result in the individual reaping some particular benefit. "The primary test of a tax is that it imposes a common burden—the primary test of a special assessment is that it implies a special benefit." This is the main distinction between a special assessment and a tax, and the others arising from it may be summarised as follows\* :—

1. In a special assessment the special benefit to the individual is measurable. In a tax the special benefit does not exist, or, if it exists at all, it is an incidental result of the share of the individual in the common benefit, and is not separately measurable.

It is further important to distinguish between a special assessment and a special rate. A special rate is assessed for the purpose of some special work undertaken by the municipality, and is levied on a defined section of the inhabitants—*e.g.*, the Poor Rate and the Lighting Rate. Such rates are assessed on what is taken to be the "means" of the ratepayer, to whom no special and measurable benefit accrues. In the special assessment, however, the individual benefit is capable of measurement, and forms the basis of the assessment.

2. Taxes may be proportional to property or to income, or to some other test of faculty, or they may be progressive rather than proportional. Special assessments can never be progressive, but must always be proportional to benefits. In the special assessment there must be compensation. In the tax there is no question of compensation.

3. Special assessments are confined to specific local improvements, while taxes are not so limited.

4. The local authority, in the case of a special assessment, performs some special act in return, while in the case of a tax it does not bind itself to do a particular thing for the particular individual in return.

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† "Essays on Taxation," by E. R. A. Seligman, 2nd ed., New York, 1897 page 357.

\* See "Essays on Taxation."

5. Taxation is employed to meet the maintenance and sinking fund charges, whereas special assessments are used to provide capital.

Special assessments, therefore, are not taxes. They differ from taxes in the same way as fees do, since both fees and special assessments rest on the doctrine of equivalents. Fees and special assessments, however, differ in some respects:—

1. Special assessments are levied only for specific local improvements—fees may be levied for any services.

2. Special assessments are paid once and for all—fees periodically. The fact that special assessments may be paid in instalments does not affect this difference.

3. Fees are levied on the individual as such, whereas special assessments are levied on the individual as a member of a class, for there must be an assessment area over which assessment is distributed.

4. Special assessment must always involve a benefit to real estate, while fees are paid for services which may benefit other elements.

The real difficulty in special assessments lies in the details of execution.

In America it has been found that abuses, springing from two sources, entered into the administration of the system.

On the one hand, the popular eagerness for premature public improvements and consequent negligence of public officials result in gross inequalities in the apportionment of the burdens and excessive impositions on the property owner.

On the other hand, the vesting of the property owner with the sole power of initiation enables obstructionists to prevent the execution of needed public works and to evade payment of assessments after the benefits have accrued.

Recent legislation in America has sought to devise machinery to avoid these abuses, and the Omaha Municipal Law of 1897, for example, endeavours to render the system more elastic by laying down the cases in which a petition from adjoining owners is necessary before the local authority can act. An arbitrary area of about three-fifths of a mile radius from the court-house square is fixed, and within this area the municipality may order paving and other street improvements irrespective of the wishes of the owners to be assessed. Beyond these limits the Council may do original paving unless the owners object, but they may not repave unless the frontagers petition.

In nearly every case of street improvement the municipality is benefited to a greater or less extent, hence in some American cities provision is made for the local authority paying part of the cost, one practice being to defray the cost of paving the street intersections.

The following tabulated statement, showing methods of paying for street improvements in the United States of America, has been extracted from "Street Pavements and Paving Materials," by G. W. Tillson, C.E.

City.	Grading, How Paid.	Original Paving, How Paid.	Repaving, How Paid.
Atlanta, Ga. ...	By City at large	2/3 by abutting property owners, 1/3 by city at large	2/3 by abutting property owners, 1/3 by city at large
Baltimore, Md. ...	All by abutting property owners	All by abutting property owners	All by city at large
Boston, Mass. ...	All by abutting property owners	All by abutting property owners	As original, except when done by special act of legislature
Cincinnati, O. ...	2 p.c. by city at large, 98 p.c. by abutting property owners	2 p.c. by city at large, 98 p.c. by abutting property owners	All by abutting property owners
Indianapolis, Ind. ...	All by abutting property owners	All by abutting property owners	By city at large
Louisville, Ky. ...	All by abutting property owners	All by abutting property owners	By the ward, except when on concrete foundations, then as original improvement
Milwaukee, Wis. ...	All by abutting property owners, except intersections, which are paid for by city at large	All by abutting property owners except inter-sections, which are paid for by city at large	By the abutting property owners, except inter-sections, which are paid for by city
Minneapolis, Minn.	By the ward	By the abutting property owners, except inter-sections, which are paid for by city	All by abutting property owners
Newark, N. J. ...	All by abutting property owners	All by abutting property owners	3/4 by abutting property owners, 1/4 by city at large
New Orleans, La. ...	3/4 by abutting property, 1/4 by city at large	3/4 by abutting property owners, 1/4 by city at large	By city at large
New York City. ...	All by abutting property owners	All by abutting property owners	All by abutting property owners, except inter-sections, which are paid for by city at large
Omaha, Neb. ..	1/2 by abutting property owners, 1/2 by city at large	All by abutting property owners, except inter-sections, which are paid for by city at large	By city at large
Philadelphia, Pa. ...	By city at large	All by abutting property owners	All by abutting property owners
Portland, Ore. ...	All by abutting property owners	All by abutting property owners	All by abutting property owners
St. Louis, Mo. ...	By city at large	All by abutting property owners	All by abutting property owners

The argument of practical expediency, as well as that of equity, requires that special assessments should be resorted to in the case of Johannesburg.

The municipality has become responsible for the maintenance of several hundreds of miles of streets, practically all of which require to be constructed as well. So far as operations have gone, it has been a rare exception to find a substantial foundation on which a new surface can be laid. In England the municipalities do not assume the responsibility of maintaining streets until they have been satisfactorily paved, sewered, and lighted. The owners have not borne the expense of paving and sewerage the streets in Johannesburg, and it is contended that they may fairly be called upon to do so.

Johannesburg has grown, and in all probability will continue to grow, with abnormal rapidity, and it is impossible for the borrowing capacity of the town to keep pace with its requirements. Either, therefore, those improvements so urgently needed must wait, or some other means than borrowing must be resorted to in order to raise the money required. It is estimated that about £2,500,000 will be required to construct the roads, and about £2,000,000 for sewerage the town, a total of about £4,500,000.

It must not be forgotten either that the interest and sinking fund charges on a loan of  $4\frac{1}{2}$  million pounds at 4 per cent. would involve an annual payment of £260,235 in order to repay the amount in 30 years, and that at the end of this period a total of £7,807,050 would have been paid for the loan.

If the special assessment system were adopted, a small loan only would be required to start with, and the special assessment payments coming in would enable the work to be continued without further borrowing.

It is undesirable to impose too heavy a liability on property owners, and hence it is suggested that special assessments should be limited to construction and not to maintenance, the town assuming the responsibility for the latter.

The nature of improvements for which special assessments may be levied will also require to be laid down, but at present we are immediately concerned with roads, sewers, and storm water drainage, and for these special assessments may fairly be resorted to.

As regards the basis of assessment, it is obviously desirable not to tie down the apportionment to the foot-front system, and to give as much elasticity as possible. The foot-front system, if laid down as a hard and fast rule, would mean that a shallow property with a long frontage would pay too much and a deep property with a short frontage too little. It is suggested, therefore, that the municipality should be empowered to take into consideration the greater or less degree of benefit derived by any premises from the works undertaken, and to include any premises not adjoining the street but deriving

benefit from the improvement, in addition to the power to apportion on the foot-front method. This would enable exceptional cases to be judged on their merits.

The municipality should also have power to pay a share of the cost of constructing streets. It is obvious that the town as a whole is benefited by the construction of wide streets in the central portion of the town and in the main suburban thoroughfares, and the frontagers would naturally object to pay the cost of streets which were wider and better finished than their individual wants required. The definition of a central area within which the municipality would contribute would not meet the case of the main suburban roads. It is suggested, therefore, that the amount of the contribution, if any, should be left to the municipality to determine in each particular case.

In the case of sewers, it would be preferable to assess the cost of each area as sewered on the property owners and not to deal with individual streets, owing to the fact that some streets would have a main sewer laid in them, which would be of no greater advantage to the owners than one of a smaller size. The outfall sewer and outfall works are of general interest, and should be paid for out of the general funds.

With regard to the question of whether improvements are only to be made after petition from a majority of the frontagers concerned or whether the municipality may initiate such schemes irrespective of the views of those interested, the best method would appear to be to place the power in the hands of the local authority, the frontagers having the right to place any objections they may have before that body. If the owners are alone allowed to take the initiative the door is opened to obstruction. There is, of course, the possibility that by giving the municipality the right to make improvements without petition premature works may be undertaken and the owners subjected to unnecessary burdens, but the municipal legislation of the Transvaal has been framed on the basis of giving large powers to local authorities and to trust them to exercise those powers wisely. There is little reason to believe that this trust is misplaced and that the powers will be misused.

A suggested procedure is that plans, estimates and provisional apportionments should be prepared by the Town Engineer and a notice published that these documents may be inspected and objections lodged. Any objections should be considered by a special committee and the decision of the Council arrived at on this committee's report, objectors being given the right of appeal to the Resident Magistrate, whose decision should be final.

Owners should be allowed to either make their payment in a lump sum or to spread them over a period of, say, three years, with interest at, say, 6 per cent.

The approximate amount of special assessments for a household of five persons, with a 50 ft. frontage, has been calculated at £49 15s. 6d., made up as follows:—

*Road Construction	...	...	£8	10	0
Footwalks	...	...	5	13	0
Kerbs	...	...	6	7	6
Gutters	...	...	4	5	0
Sewers	...	...	10	0	0
Stormwater Drains	...	...	15	0	0
			<hr/>		
			£49 15 6		
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\* This amount is based on the cheapest class of road.

It must be remembered that in most cases the charges for roads, sewers, and drains would not be all payable at the same time, and that the total would, therefore, be probably spread over considerably more than three years. In any case, the amount is a small one when the benefit of the improvements is taken into account.

Finally, to quote Dr. Rosewater\*:—"With few exceptions and abuses it (the system of special assessments) has operated in the United States to the general satisfaction of all. It rests upon principles of right and justice. It brings quick results at the very time when needed. It discourages the speculative holding of unimproved urban property. Its introduction, like that of every new plan for raising revenue, may, in places where other methods have long prevailed, involve conflicting considerations of expediency. But for young and rapidly growing municipalities, the system of special assessments is undoubtedly the best, the most practicable, the most just."

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\* Op. cit., p. 149.

### 43.—THE PREHISTORIC MONUMENTS OF RHODESIA.

By F. P. MENNELL, F.G.S.,

From the earliest times that Europeans have had intercourse with South Africa vague reports have been current of mysterious structures regarding which the natives had no traditions and as to whose characteristics, even, no reliable information was for long to be obtained. The first accounts were those which Arab traders gave to the Portuguese. They stated, in the words of the historian De Barros, that amongst the mines of the country of Monomotapa was a "fortress of masonry within and without, built of stones of marvellous size, and there appears to be no mortar joining them. The wall is more than twenty spans in width, and the height is not so great, considering the width. Above the door of this edifice is an inscription which some Moorish merchants, learned men, who went thither could not read, neither could they tell what the character might be. This edifice is almost surrounded by hills, upon which are others resembling it in the fashioning of the stone and the absence of mortar, and one of them is a tower more than 12 fathoms high." This account is the first published of Zimbabwe, and is evidently taken from a very fairly accurate description of the famous ruins. Several discrepancies are certainly introduced, but they are just such as would naturally occur in relating from memory what was heard some time before. A good deal of confusion has been caused by the description of several other Zimbabwes, and by the application of the name to the kraals of various powerful chiefs. In this case the name is not used at all, but the locality is given as a hundred and seventy leagues or thereabouts due west of Sofala, and between 20 and 21 degrees south latitude, so that there is no doubt that Zimbabwe is really meant, quite apart from the description. I desire to emphasise this point, because of the uncertainty I previously expressed in my account of the Zimbabwe ruins, an uncertainty speedily removed by perusing the translations of original documents now made available in the "Records of South-East Africa," issued by the Cape Government. Numerous references are made to ruins near the court of the paramount chief of the country, "Monomotapa" or "Mambo," which was obviously in the Mazoe district, and of which the Portuguese writers could speak from personal knowledge. The only other reference, however, among the early writers, to Zimbabwe itself which is not a mere copy of the abovementioned statement is that of Father Monclaro, who accompanied Barreto's expedition in 1572. He says: "There is also another kingdom adjoining this Mocaranga, which is the kingdom of Besa, where there is a palace of the ancient Monomotapas which the Kaffirs hold to be a supreme piece of work. All the Monomotapas are buried there, and it serves them as a cemetery." In connection with



this, it may be remarked that a chain of mountains close to Zimbabwe is known as the Beza range, and the name may well be a survival of that mentioned by the Portuguese writer. Many of the ruins bear traces of long-continued Kaffir occupation, and it was only a few years ago that the hill ruins at Zimbabwe were vacated by a tribe who had perched their huts amongst the rocks, and sometimes even on the ruined walls. This leads to the certainty of much confusion from an uncritical examination of the finds that have been made from time to time. The natives have, however, practically no ideas concerning the origin of the ruins, certainly none which are calculated to throw any light upon the subject. The fact is that the Kaffir does not trouble himself with speculations about such matters, but he is nevertheless rarely at a loss for an answer, and will generally give a plausible reply to a question even if he never heard of the subject before. De Barros relates that he was told the ruins were "the work of the devil," no doubt, as he truly says, because "in comparison with their power and knowledge it does not seem possible to them that they should be the work of man." It is important to remember that his history was written some 350 years ago, and that this was the statement of people whose ancestors have in all probability inhabited the country at least from the commencement of the Christian era. At the present day natives frequently assert that "the Umlimo built them," the being in question being their nearest conception of anything in the nature of a god, and this is no doubt what De Barros himself heard. That they were "always there" is another common statement, and one is often put off by the counter question, "Do not the books of the white men say?" A curious saying is that they were built when stones were soft, an idea which forms a remarkable parallel to the statement of some of the South American Indians regarding the cut and drilled gems found in their country.<sup>1</sup> The Matabele often say that the Abalosi built them for cattle kraals, and this is usually supposed to refer to some of their predecessors in the country. The Makalunga, however, themselves sometimes talk of the "Abaroswe" as the builders, and I am informed that the remnant of such a tribe actually exists in Mashonaland. Probably they were at one time much more numerous and important than now, but their connection with the ruins rests on no sounder basis than the more obviously fabulous accounts.

The Bantu are considered by some authorities to shew signs of being a degenerate race, but even if this be so, we can scarcely by any stretch of the imagination credit their ancestors with the conception and execution of such remarkable monuments. Professor Tylor,<sup>2</sup> indeed, is willing to accept them as evidence of a much higher civilisation among the race in former

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<sup>1</sup> See Tylor, *Early History of Mankind*, p. 187.

<sup>2</sup> *Primitive Culture*, p. 47.



times, but he admits that colourable evidences of degeneration are very rare.<sup>1</sup> The testimony of El-Masoudi, writing about 930 A.D., shews that in his time the people here were Kaffirs with precisely the same customs as now, and an Arabic inscription which has recently been brought to light<sup>2</sup> proves that in the year 95 of Hira, i.e., 713-714 A.D., the Arabs had already penetrated inland, and must have known if any higher civilisation had then existed. Indeed it scarcely seems necessary to argue against the possibility of a people like the Kaffirs having originated the ruins, people who for generations are content to make a circuit round a stone it would not take them a minute to remove, and whose superstitions require them to remove their kraals to another place when the headman dies. Is it conceivable that such a people should originate and carry out public works of the first magnitude, which, allowing for differences in architectural ideals, equal, if they do not surpass, anything that the European has done in the four hundred years since he first set foot on the southern half of the African continent? Or will it be credited that people capable of carrying out such a scheme as the great temple at Zimbabwe, with its massive stone walls 30 feet high and 15 feet thick, should not only be content to live in mud huts surrounded by a fence of thorns, but have actually lost all traces of the form of religion which prompted its erection? And if we go back to the days before the invading Bantu overspread the land, we have every reason to believe that the Bushmen were the occupants of the inland plateaux, and the Hottentots of the coastal regions. These races are far lower in the scale than the Bantu, neither having reached the stage of cultivating crops or working the useful metals. The former, indeed, dwelt in caves and rock shelters, destitute of all save the rudest arts, and affording to the present day an illustration of the life and habits of paleolithic man.

It seems, therefore, almost as if we must attribute an external origin to the mysterious structures that we are considering, and we must certainly look to the ruins themselves for further evidence. And even in dealing with the features that they present, it is perhaps premature to make generalisations of a sweeping character. Though the existence of several hundred distinct structures seems probable, there are only six of any importance of which a reliable description is extant, and each of these has features which are seen in none of the others. It may be as well to enumerate these six with the authors who have described them. They are: Zimbabwe (Bent, Willoughby, Mennell); Matendele (Bent); Khami (Gill, White, Mennell); Dhlo-dhlo or Mambo (White); Regina (White); Nanatali (Popham). The published accounts of other ruins are mere hearsay statements of untrained observers or the work of those

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<sup>1</sup> *Loc. cit.*, p. 57.

<sup>2</sup> See Lane-Poole, *Proc. Roy. Irish Acad.*, Vol. XXIV., Sec. C., pp. 47—54

who have been convicted of grave inaccuracies in the case of known ruins. What follows is, therefore, founded on the accounts specified, supplemented by the author's personal observations of a number of smaller ruins.

The area in which the ruins occur is one defined by striking natural features: the Zambesi on the north and the Limpopo on the south, the desert on the west, and the ranges bordering the plateau to the east. So far as I can discover, there are no ruins in Portuguese territory, though it is often asserted that they extend to the coast. They appear to be fairly evenly scattered over the extensive tract in which they occur, and afford precisely similar features, allowing for a certain amount of variation in details throughout the whole area.

The material used is invariably stone, and always granite where procurable. This is even the case where it has had to be transported from a distance. In some instances other rocks are used, as sandstone at Wankies, and schist and banded ironstone on some of the more extensive areas of metamorphic rocks. Single courses, slabs, posts, etc., of dolerite, hornblende, talc, or chlorite schist, banded ironstone, quartz, and even wood are often introduced for decorative purposes or for constructional details where the granite has evidently not been readily reduced to the required shape. Unlike the Egyptian, Phoenician and other monuments of historic ages and the European phallic structures of more remote antiquity, large blocks of stone are never used; on the contrary, they are very small, considering the material, not greatly exceeding the size of an ordinary brick.<sup>1</sup> Large boulders of granite, however, have sometimes been left *in situ* and walls built over and around them. The blocks of stone are always carefully trimmed on their outer faces, and laid together without mortar, though a kind of cement, evidently hardened by burning, is almost invariably to be found, sometimes covering the floor and even laid over stonework, especially steps. In thickness the walls vary from two to twenty feet, and the height may be anything up to thirty feet, though frequently not more than six. The courses are usually very even, but sometimes die out as they are continued, smaller and smaller stones being introduced until they abut against a stone of the course below, which is slightly above the usual level. Such "false courses" are observed even in the great cone and the temple wall at Zimbabwe, which are probably as perfect examples of the dry-builder's art as are anywhere to be seen. Foundations are either more roughly built, and somewhat wider than the superstructure, as at Zimbabwe, or of rather larger stones as at Khami. Artificial levelling of the ground is often found, as well as the construction of mounds to raise the

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<sup>1</sup> The size of the blocks is readily explained by the fact that the granite weathers by a process of scaling off in large sheets from a foot to an inch or two in thickness. Blocks a few inches thick are therefore obtainable in any quantity by merely breaking up one of these "shells" into pieces of the required size.

central part of the ruin, as at Nanatali and Zimbabwe. Where the walls are built round a small rise, as is often the case, terracing is a frequent feature, or in the case of steep scarps, the walls, after rising to a certain height, are stepped back a few feet. Khami, Dhlo-dhlo, Regina, Nanatali, and the hill ruins at Zimbabwe all shew excellent examples of these types of construction. The filling in as far as the retaining wall is done with rough stones, covered with cement flooring, and both at Regina and Nanatali, curious circular holes or pipes, carefully built round with dressed stones, are found descending through the rubble. These may be for drawing off surface water from the cement floors, like the square but nearly horizontal holes through the walls both of the temple and the hill ruins at Zimbabwe. Terracing, etc., are naturally not seen where the structure is on perfectly level ground, as the Zimbabwe temple and some of the smaller ruins at Khami. In such cases great stability is given by a considerable batter back, so that a wall 16 feet at the base, for example, is 9 or 10 feet at the top, about 30 feet from the ground.

At present there is no criterion which enables us to distinguish between the civil and religious architecture of the ancients, especially as in most cases it seems probable that the ruins were adapted for both religious and military purposes.

Nearly all the larger structures are of roughly circular outline, often with considerable irregularities depending on the contour of the ground. They are divided into compartments by means of walls, which approximately represent arcs of smaller concentric circles, intersected by radial walls, which would pass through the centre if continued, but which usually start from the sides of a small circular enclosure in the middle of the building. These radial walls are never perfectly straight, and rarely shew a well defined angular junction or corner. They are not dovetailed into the walls they meet, but simply abut up against them, even in instances where they curve considerably so as to avoid forming a sharp corner. Indications of roofing are extremely rare, though in some cases, as at Khami, Dhlo-dhlo, and Regina, passages appear to have been covered, and occasionally wooden posts are let into the walls as if to form supports for beams. These exceptions, however, only serve to emphasise the general absence of such indications, and it may be asserted with considerable confidence that most of the buildings are simply enclosures never intended to be roofed in. Indeed, the roofing of such a structure as the temple at Zimbabwe or the ruins at Regina, Nanatali and Dhlo-dhlo would be no mean engineering feat at the present day.

There is abundant evidence, however, that while some of the entrances were mere gaps, or breaks in the continuity of a wall, others were similar to modern doorways, the upper courses of the walls being carried across them. The ancients had no knowledge of the principle of the arch; lintels of stone or wood

are always used. Bent states that the north-west entrance of the temple at Zimbabwe had wooden lintels, though apparently no traces now remain. On the hill, however, of the two covered gateways, one, nearly fallen in, shews a wooden lintel, while the other is carried over slabs of chlorite schist. At the 'Mpako ruins in the Victoria district, which I examined in September, 1902, there is a fine covered entrance to one of the enclosures. It passes through a wall fully 4 ft. thick, which is carried over five slabs of granite, and shews the curious partial walling up of an originally larger gap, just as Bent describes in the case of Matendele ruins. The ends of the walls are in this instance square, while at Zimbabwe they are rounded. It may be mentioned that at two entrances in the Temple at Zimbabwe the walls on either side have each one corner square and the other rounded off.

A curious feature of many entrances are the structures sometimes called buttresses, which they by no means resemble in function, though they may in appearance. They are always rounded or shew two curved sides meeting at an angle, and are sometimes almost detached from the wall, having only a small segment cut off by it. One such at Khami was evidently capped by a large circular slab of stone, now fallen. Some of these structures are obviously of a utilitarian character, narrowing passages and having grooved recesses into which a number of stone slabs might be inserted to form a kind of port-cullis. These recesses are also seen in the ordinary entrance ways and even along walls, where they sometimes shew upright stone or wooden posts whose use is somewhat of a mystery. At Nanatali there are circular holes in the cement floor just by two of the entrances, and it has been very plausibly suggested that they held totem posts or objects of a similar character. By the entrance to one of the valley ruins at Zimbabwe the stump of such a post is still to be seen.

One of the most interesting structures in Rhodesia is the cone at Zimbabwe, which is a solid mass of masonry built in the same way as the walls of the ruins, about 35 feet high and 18 feet in diameter at the base. This, taken in conjunction with the phalli which have been found, places the religious character of the great circular building and the form of religion practised beyond a doubt. The cone, whose meaning is not at all clear, replaces in nature-worshipping temples the statues and images of other cults and in the case of the Phœnicians was placed in an unroofed enclosure just as at Zimbabwe. Nature-worship, however, was one of the most widespread religions of antiquity, and therefore affords no clue to the builders, except in so far as it excludes the Mahometan Arabs and other races that have been suggested. A circular erection, 21 feet in circumference, stands besides the great cone, and has usually been taken as a smaller structure of a similar character. This would form a parallel to the custom of the Aztec sun worshippers of Mexico, who by the

side of the pyramid dedicated to Tonatiuh the sun, placed a smaller one for Metztli the moon. There are, however, grave doubts, to my mind, whether this almost completely ruined structure was really a cone at all; I am much more inclined to think that it may be the altar, of which otherwise all traces have been obliterated. The cone and the altar, if such it be, are placed in a kind of swelling in the curious passage, very narrow east of the cone, which runs half-way round the temple. The enclosure would not hold a large number of people, but it is overlooked by a platform on a much higher level, where the principal devotees no doubt took their stand. Such platforms are a constant feature of the ruins. On Zimbabwe hill there is one partly natural and partly artificial, on which several tall rough pillars of stone are placed, and another, almost entirely natural, on the highest accessible point, which commands a magnificent view of the surrounding country. The function of these platforms is evidently somewhat different to those in the temple, and they remind us forcibly of the "high places" of Baal worship. Both are approached by narrow passage ways. The former has stone steps upon one side, while on the other it is reached by a winding way through the two covered entrances that have been mentioned. The latter has an approach through a cleft between two rocks, which meet overhead.

Narrow passages and tortuous ascents are a marked feature of certain ruins. Thus the hill ruins at Khami and Zimbabwe are both placed on high kopjes, with protecting walls along every point where the ascent is at all practicable, while precipitous faces have no such safeguards. The approaches, especially at Zimbabwe, are very narrow, and protected with walls on either side, and are commanded by numerous enclosures, which would form admirable points of vantage for a defending force. The way, however, is made easy for authorised persons by winding to avoid difficult places and by steps carefully built of stones and sometimes covered with cement at the steeper slopes. There are, besides, curious recesses, with steps ascending towards the back, which is, however, formed by an unscaleable wall. As before mentioned, parts of these passages appear in several instances to have been covered, and a recess at Khami has wooden posts, which Mr. Franklin White has suggested formed supports for a light roof.

The walls of many ruins show features which are obviously intended as architectural embellishments, though some may possibly have had a religious significance also. Courses of dark-coloured stones are often introduced to contrast with the granite, or the arrangement of the blocks is varied so as to produce various patterns. The commonest decoration is the chequer pattern, produced by leaving gaps between each stone, while chevron, dentelle, sloping block, and herring-bone patterns are also seen, especially the last-named. These have already been described and figured by Mr. White in the first



report of this association. Statements have been made as to their facing in particular directions, but in a single ruin they may be found facing every point of the compass, and the only case in which such an idea seems to have any foundation is that of the chevron pattern on the temple at Zimbabwe, which roughly indicates the part of the wall which is illuminated by the rising sun at mid-summer. Pillars of stone, sometimes rough slabs of granite or schist, and in other cases elaborately carved talc are found inserted at intervals along the tops of the walls. At Zimbabwe these were often carved in the shape of a bird of prey. Small towers also rise above the general level of the summits. These are round at Zimbabwe and square at Nanatali, where they are placed on a cement base. In both cases they are connected with the pillars already mentioned, alternating with the latter at Zimbabwe and surmounted by them at Nanatali.

Outside the large edifices whose features have been alluded to in the foregoing pages there are some small structures which merit notice. At the Regina ruins there is a series of what can only be termed cromlechs on a small scale, of which descriptions and photographs have been given me by Mr. H. W. Garbutt. They are only a foot or so in height, but the chief impression received from a photograph is the striking similarity to Stonehenge. What their object may have been I am at a loss to conjecture. I have also seen circles of upright stones about 18 inches to 2 ft. high in the Umsingwane Valley, due south of Taba-s-Inyoka, which are also strongly reminiscent of neolithic structures: they may, however, have no connection with the ruins. Other circles of a different nature, looking like the foundations of huts, are seen at Matendele, Nanatali, Khami, and 'Mpaku. They are sometimes cemented over, and show spaces where poles were inserted or even remains of the poles themselves. These circles are of great interest, as possibly shedding some light on the domestic architecture of the ancients. We can scarcely suppose that the enclosures that have been described were intended for dwelling places. In a few instances, as in the case of a curved wall with post holes on Zimbabwe Hill, we may suppose that there was a roof, but these are only rare exceptions. The massive ruins, that are often all that we now see, must have formed merely the nucleus around which clustered the slighter wooden structures where dwelt the meaner inhabitants at least. Some of the principal men may have, and indeed no doubt did, reside within the walls, but the latter seem to have been intended primarily as a protection against attack and as places within which gold working operations could be carried on in security and seclusion.

That gold mining had a great deal to do with the building of the ruins no one can doubt, from the number of evidences of smelting the precious metal and working it up into beads, wire, chain and other ornaments that have been found. At the same

time it is remarkable that nearly all the ruins are on the granite which never contains gold reefs. The so-called "ancient workings," which are so numerous throughout Rhodesia, are also certainly, in nine cases out of ten, comparatively modern. The Arabs are known to have traded with the natives for gold at Kilwa and Sofala for fully five hundred years previous to the Portuguese discoveries, while the Portuguese continued the trade, and even essayed mining on their own account. It has been contended that this native mining was only for alluvial, but the early Portuguese writers describe quartz mining,<sup>1</sup> and point out that the gold thus obtained is of less fineness than alluvial. Father Monclaro further mentions<sup>2</sup> the manufacture of gold ornaments by the natives, and I learn from early settlers here that many of the Makalanga possessed gold bangles, etc., before the Chartered Company's occupation of Mashonaland. Selous<sup>3</sup> adduces good evidence that the natives continued gold mining to the present day. These considerations, together with finding Kaffir hoes and even such perishable articles as mealie cobs at considerable depths, are quite sufficient to cause grave doubts as to whether any of the workings opened by the ancients are likely to have been left in their original state to the present day. The Kaffir no doubt reopened the cuttings of his predecessors, just as the modern prospector has done, even if the former's knowledge of mining is not directly traceable to the influence of the older miners.

The subject of mining brings us naturally to the consideration of the tools, implements, etc., of the ancients. My first impression was that the dressing of stones in the way it is done at the various ruins was practically impossible without iron, or at least bronze, tools. A very careful examination of large numbers of the squared blocks has caused me to abandon this opinion, as the fractures are not of such a character as would be the case if edged tools of metal were employed. Further, no metals except gold and copper appear to have been worked; so-called objects of bronze are always of unalloyed copper. This is the case even with spear-heads found at Dhlo-dhlo and Zimbabwe. With the exception, too, of boring holes in certain oval stones, there is never any attempt at incised or engraved work in the case of any other material than talc ("soapstone"), which can be furrowed even by the finger nail. Numerous chipped and ground stone implements have been found, and altogether the evidence at present seems almost to necessitate our referring the building of the ruins to a date even prior to the use of bronze, that is to say, antecedent to 1500 B.C.<sup>4</sup> It may be pointed out, however, that tin is of such extreme rarity

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<sup>1</sup> See Dos Santos ; Records of S.E. Africa, Vol. VII., p. 218—9.

<sup>2</sup> Rec. S.E. Africa, Vol. III., p. 234.

<sup>3</sup> Geog. Journal, Vol. I., No. 4, p. 308.

<sup>4</sup> See Gladstone, Nature, April. 1898, pp. 594—8.

in South Africa that no indigenous race would be in any way likely to discover its utility in hardening copper, though in this connection it is of great interest to note that a few small buttons of smelted tin, together with two or three beads made of the same material, were found at the Khami ruins some years ago, and are now in the Rhodesia Museum.

It is not my purpose on the present occasion to further discuss the objects found in the ruins, though they throw much light on the degree of civilisation existing among the builders. They had undoubtedly attained a high state of what may be termed barbaric culture, very similar to that of the Aztecs, though it apparently fell short of the employment of written characters or even of picture writing. Whether their civilisation was of purely indigenous growth, or whether they brought with them the arts of another land must remain a moot point until we are in possession of further facts. At present we can scarcely be said to have even a working hypothesis to go upon, and the evidence necessary for a definite solution of the problem is only beginning to be collected.



## 44.—INYANGA FORT.

### A REPORT OF AN EXAMINATION OF THESE RUINS.

By R. N. HALL, F.R.G.S.

(Plate XLIV.)

These ruins are situated two miles south-east of Mr. Rhodes' farmstead, on the comb of the ridge of a long kopje which runs from north-east to south-west. The hill rises steeply on either side of the line, but ascends in gentle slopes at its extremities. The ruins command a strong strategic position, and a most extensive view, and overlook valleys and downs which are thickly covered with the remains of stone dwellings and walls. The precipitous cliffs of Inyanga Mountain (9,000 ft. above sea-level) rise in gigantic form some four miles to the east. The valley on the summit of the Inyanga Range shows country fair and fertile, stretching in one azure sea of hills and valleys to Nani (fifty miles), and on towards Katereris (sixty miles). Towards the west is a similar view, extending in giant steppes in the direction of Headlands and Marandellas. The southern view is narrowed by the giant granite bluffs of York Hills, while Major Van Niekerk's farmstead fills in the nearer distance. To the south-east, at a distance of some three miles, can be seen against the sky-line similar ruins to the Inyanga Fort, only smaller, but in a better state of preservation. This is on the eastern side of the summit of a balloon-shaped kopje, whose northern face is steep and inaccessible. These are known as the "Bideford" Ruins, being on the Bideford Farm, on Mr. Rhodes' estate.

The farmstead Fruitlands, our headquarters, appears to be far below in a valley, though actually it is built on the face of a hill. Numerous cascades in several valleys appear to be but streaks of white, and kraals and other objects below can only be discerned with the aid of field-glasses. Camping out at these ruins at this high elevation (7,000 ft.), one is in a keener atmosphere, far cooler than at the farmstead, and the nights are found to be much colder. Mists envelope the hill at times, but they roll on and off very quickly and suddenly. The scenic effects produced by these mists are exceedingly fine and weird, and the contrast between the opaque wall of vapour and the sunny valleys shown through passing rifts is most indescribably fascinating. The usual daybreak view from this point is of hundreds of sun-bathed rocky islands standing out from a white sea of mist, or a fleeting Alpine view in miniature.

#### AREA.

The area covered by these ruins, excluding traces of terraces and walls immediately surrounding them, is 200 ft. from north to south and 250 ft. from east to west.

## PLAN AND CONSTRUCTION.

All the walls, with the exception of two, one being of very poor construction, are built upon a curved plan. In other respects the features are angular, the walls are perpendicular or with most imperceptible batter-back, the entrances are singular and not rounded, and all the loop-holes are square. The plan very closely resembles the rising-terrace or wedding-cake style of building which crown and cover the summit of hills in a portion of western Matabeleland, but it would be unwise at present to place too much reliance on the parallelism.

A close inspection leaves a strong impression of a combination of both skilled and unskilled design and construction, extremely difficult to reconcile owing to contradictory evidences. This combination of crude and unskilled workmanship suggests that the actual labour was that of a very old native people, with the inclusions of features of architecture conveying the idea of at least some direction and supervision by a more skilled race of builders. This impression is strengthened when one considers the presence in the very vicinity of such buildings as that now being described—a type of many others in the Inyanga district—of aqueducts miles in extent, which score the faces of the hills in this and corresponding areas, and which aqueducts, as well as the associated hill terraces, must have been the work of skilled engineers, and not that of any native people left to its own power of initiative.

The building material employed is of the country rock—blue slate, and this yields itself in rough boulders and slabs—which, when used in walls afford the builders no opportunity of keeping many courses or of attempting to distribute the joints or to bond the stones, thus leaving fissures and gaps between the stones, which are filled in with small stones.

One other prominent feature in the construction of the walls is that instead of laying the slabs on their flat sides, these are set up on their edges in a vertical position in the outer faces of the walls, with their broad face outwards. Some of these slabs are large, heavy, and shapeless, and these are to be seen even in the higher parts of the wall. There is no sign of any of the stones ever having been dressed. This style of architecture has a parallel in a minor ruin at Zimbabwe, which is not, for very many reasons, believed to be ancient.

## MURAL DECORATION AND MONOLITHS.

These are entirely absent from these and similar ruins.

## COVERED ENTRANCES.

These are very numerous, both in outer main walls and also divisional walls. They are all angular, have large slabs of stone placed over them for roofing, and

none have any portcullis grooves. The average measurements of these entrances run as follows:—Floor to roof, 3ft. 10in.; width, 2ft. 2in.; length through wall, 6 ft.; length through banquette wall, which runs round the inside of the main and some of the divisional walls, from 3 ft. to 5 ft.; the total length of covered entrance passages averaging from 9 ft. to 12ft. There are covered entrances still intact, and some others which are now roofless and dilapidated.

#### LOOP HOLES.

In all walls, both main and divisional, there are square loopholes which run through both wall and banquette, thus giving them a length of from 8 ft. to 12 ft., according to the width of the banquette. The holes are no less than 12 in. by 12 in., and all are fairly well squared throughout their length. These holes are in rows at about 3 ft. to 5 ft. above the ground, but they are not all exactly on the same level. The holes are fairly distributed along and around the walls. It would be quite possible to shoot an arrow through the shorter holes, but natives affirm that this could also be done through those of the longer ones which are still perfect. The total number of these holes at these ruins must be at least fifty. There appears to have been very few loopholes in the walls above the banquette walls, possibly as the banquette inside the main wall would enable anyone standing upon it to see over the main walls to the exterior of the building.

#### BANQUETTE WALLS.

The general adoption of substantial banquette walls as a means of defence in this and similar buildings in the Inyanga district, is somewhat striking, especially as their employment in old ruins in Southern Rhodesia, Inyanga excluded, is not very frequently met with. These walls are really part of the main outer walls, and also of some of the divisional walls, but are only carried up to a height of from three to four feet above the ground, thus forming an elevated terrace walk, varying in width from two to five feet all round the inside of the walls, which would enable the defenders while occupying a protected position to see over the main wall, or to throw spears and missiles on to the enemy outside the walls.

The original designers of the building evidently bore in mind the possibility of the outer and lower defended enclosures being captured by an enemy, for they have provided a further line of defence in a higher and central enclosure, IV. on Plan (see Plate XLIV.), and this has also banquette, loopholes, and small covered entrances overlooking and commanding enclosures I., III., V., and VI., while enclosures II. and III. have similar defences against a possible hostile occupation of enclosure I. The redundancy and repeti-

tion of such methods of defence, with their remarkable evidence of caution and foresight in the provision of successive lines of defence demonstrates a knowledge of military tactics on the part of the designers, which one cannot well conceive to be of purely native origin.

#### ABSENCE OF BUTTRESSES.

In these ruins, and in many of their class in this district, there is an utter absence of buttresses, either angular or rounded, which form such prominent features in the ordinary ruins of Matabeleland and Mashonaland. In such latter ruins the original builders extensively employed buttresses for the defence of entrances from attacks from the exterior, and in order to provide shelter for the defenders. In the Inyango forts, the lowness, length and narrowness of the entrance passages, together with the vantage ground afforded by the banquette wall over the interior of the exit, evidently were the only means employed to protect the entrance or to make its defences easy to the occupiers and difficult for the attacking party to force.

#### FOUNDATIONS OF STONE HUTS.

The ruins contain the foundations and side walls of some score of circular huts. No one who has ever inspected them and the thousands of other huts in this locality in places where there are no ruins, attributes to them antiquity, though admitting them to be of an age dating from some generations past and occupied by natives up to a still more recent date. This assertion as to their comparative modernity is based on many arguments.

- (1) The natives state that they built the huts when they were wont to take refuge with their women and cattle in these ruins during the frequent raids of the Shangaans, which raids ceased on the arrival of the white man.
- (2) These structures are exactly similar in every respect to the stone huts of the natives found in thousands in this district, and these found so plentifully in Mashonaland in kraals where there are no ancient ruins, or built on the upper levels of very many ruins which have been occupied up till recently by natives.
- (3) The appearance of these huts is practically modern, and dissimilar to the building in the main walls, and in some instances the huts are built of debris fallen from the main walls, and obviously old loophole and entrance roofing slabs have been moved and employed in the structure of the huts, while late native pottery is used to wedge up blocks to a level.

(4) The only finds made in these huts are the commonest of modern native articles.

The huts are of diameters varying from 11 ft. to 16 ft. The natives say they were once roofed with poles and grass, and that the huts were only occasionally occupied.

#### LEVELS OF FLOORS OF ENCLOSURES.

The ruins crown the top of the ridge on the summit of the hill, enclosure IV. being on the highest and most central point. This is surrounded on all sides by enclosures, except for some 40 ft. on the west side, where there is a sharp declivity. All the enclosures slope outwards and downwards from the central enclosure to the outer main walls of the ruins. The central enclosure IV. thus overlooks and commands all the other enclosures. Its floor is practically level, the small natural plateau enclosed being artificially extended by filling in of soil on the inside of its rampart walls. Its floor has an elevation above the highest and nearer portions of the floors of the surrounding enclosures to the following extent:—Above No. 1, 4 ft.; No. 3, 5 ft.; No. 5, 4 ft.; No. 6, 9 ft.; and overlooking the unenclosed space on the west side, 4 ft.

The floors of the enclosures surrounding the central and elevated enclosure (IV.) slope outwards from the outer base of the wall of this enclosure to the inner base of their outer main walls are as follows:—No. I. enclosure slopes 2 ft. 6 in. in 91 ft. towards south-west; No. III. slopes 5 ft. in 65 ft. towards east; No. V. slopes 6 ft. in 40 ft. towards east-north-east; and No. VI. slopes 9 ft. in 81 ft. towards east, while No. II., which does not adjoin No. IV., slopes 2 ft. in 63 ft., from No. I. towards the east-south-east.

#### DESCRIPTIONS OF ENCLOSURES.

No. I. This is the most westerly enclosure, and its shape is irregular. The area is 116 ft. from north to south, and 91 ft. from east to west. It is bounded on the south, south-east, and north-north-east sides by enclosures II., III., and IV.

The enclosure has nine covered entrances, and another can be traced in a gap on the west side. The entrance on the north-west side passes obliquely through the wall.

The heights of the walls from the interior floor are as follows:—North side, 8 ft.; west, 9 ft.; south 11 ft.; and east, 5 ft.

The banquette or terraced wall runs round the inside of the outer main wall as follows:—North side (part only), 2 ft. to 4 ft. wide, 4 ft. high (very dilapidated); west side, 2 ft. to 4 ft. wide, 3 ft. high; south-west side, none; south-east side, 2 ft. wide, 2 ft. high (traceable).

The loop holes intact—south side, eight; west, four; north, six; east, two; but others are traceable.

In this enclosure are the remains of ten stone circular huts, with diameters varying from 11 ft. to 18 ft., outside measurements.

*No. II.*—This is the most southerly enclosure. The area is 63 ft. from north-west to south-east, and 53 ft. from north-west to south-east, and 53 ft. from south-west to north-east. It is bounded on the north-west by No. I. enclosure, and on the north-east by No. III. enclosure.

The enclosure has two covered entrances on the north side, and one on the west side, and more are traceable.

The heights of the walls from the floor of the interior are: North and west, 8 ft.; south, 6 ft.; and east, 4 ft.

The banquette wall runs round the inside of the enclosure on its north, west, and south sides. This averages in height 3 ft., with an average width of from 2 ft. to 3 ft.

There are six loopholes on the west side, none on the east, one on the north, and two on the south side.

Traces of one circular hut only are to be seen in this enclosure.

*No. III.*—This is on the east side of the ruins, and is bounded on the south-west by No. II.; north by No. IV.; and north-east by No. V. enclosure. Its area is 72 ft. from north-east to south-west, and 66 ft. from south-east to north-west.

There are three covered entrances, one on the south side and two on the north-east.

The heights of the walls are: South-east, 5 ft. to 7 ft.; north-east, 4 ft. to 8 ft., and north-west 7 ft.

A banquette wall is on the south and east sides only, these averaging 2 ft. in width, and are 3 ft. high.

There are seven loopholes on the south-east and north-east side, two on the west, and three on the north.

No traces of stone huts are to be found.

*No. IV.*—This is the central enclosure before referred to (see *Plan and Construction and Levels of Floors, ante.*), and it is bounded by Nos. I. III., V., and VI., and on the north side by a partially unenclosed space 44 ft. wide. Its area is 63 ft. from north-west to south-east, and 49 ft. from north-east to south-west.

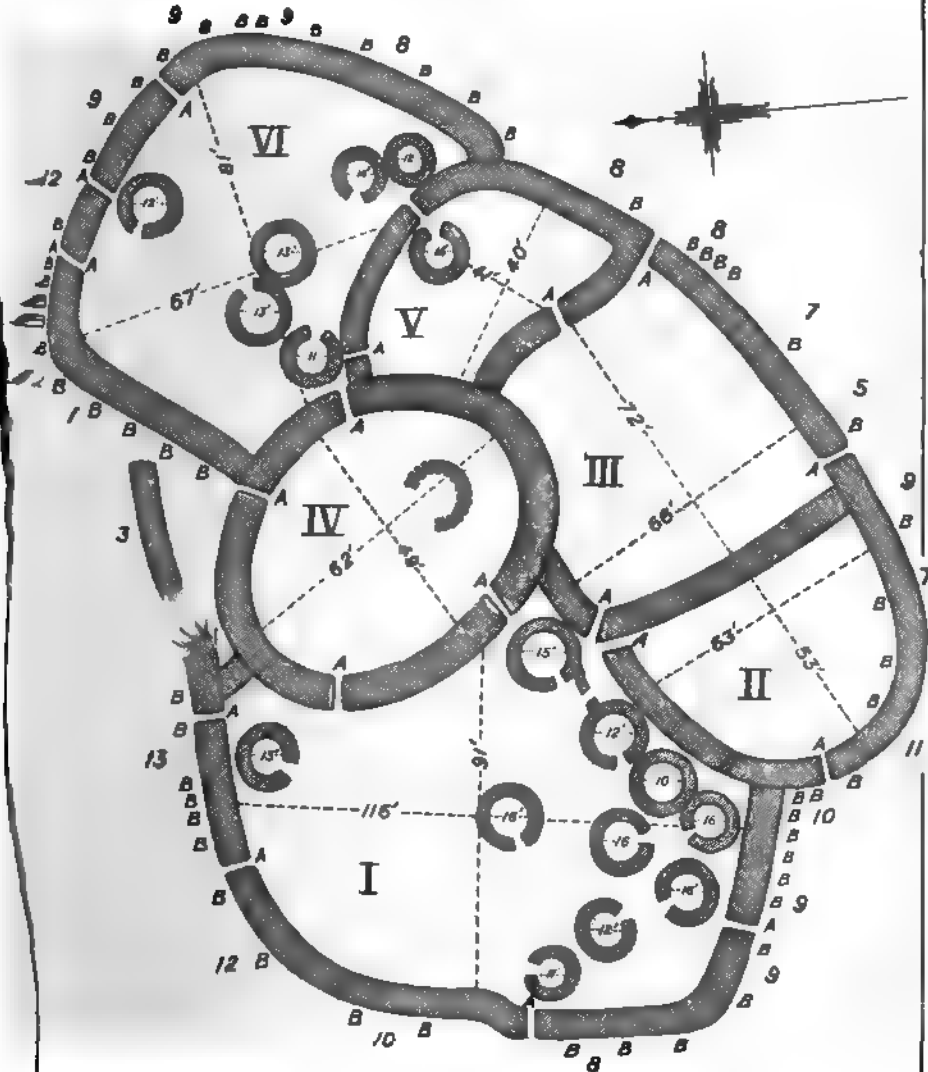
It has two entrances on the west side, and one each on the north and east sides.

The present much reduced heights of the walls above the filled-in interior are as follows: south-west, 4 ft.; north-east, 3 ft.; south-east, 3 ft.; north-west 5 ft.

The wall is of a very massive character, being in most places 10 ft. wide, but in places it reaches a width of 12 ft.

There are remains of banquette wall from 2 ft. to 5 ft. wide and 3 ft. high round some portions of the main wall, but in other parts it is considerably dilapidated.

Some twelve loopholes yet remain intact, and traces of others exist.



*A. Covered entrances B. Loopholes  
Plain figures on exterior, are heights in feet of  
exterior face of wall.*

*Inyanga Fort R N Hall*





Traces of one stone hut only are seen in this enclosure.

*No. V.*—The area of this enclosure is 4 ft. from north to south, and 40 ft. from east to west.

There are three covered entrances, two being on the north side and one on the south.

The average heights of the walls from the interior ground are: West, 7 ft.; north, 4 ft.; east, 5 ft. to 7 ft.; and south 7 ft.

A banquette wall runs along the inside of the east wall, and is from 2 ft. to 3 ft. wide, and 3 ft. high.

There are a few loopholes still intact and traces of others.

The remains of one stone hut only, with a diameter of 14 ft., is on the north side of the enclosure.

*No. VI.*—This is the most north-easterly portion of the ruins. Its area is 67 ft. from north-west to south-east, and 81 ft. from north-east to west-south-west.

There are two covered entrances on its north side, and its outer wall contains no less than thirty loopholes.

The remains of some seven stone huts are within this enclosure, and these have diameters varying from 11 ft. to 14 ft.

# INAUGURAL ADDRESS DELIVERED AT THE FIRST CONFERENCE OF SOUTH AFRICAN LIBRARIANS.

BY MR. JUSTICE LAURENCE.

*"Our pursuit of art is without extravagance, neither does our love of literature make us effeminate."*—Thuc. II., 40.

Less than a month ago I was honoured by an invitation to preside at this Conference, or, if that was impracticable, to prepare an address to be delivered at its opening. To that invitation I replied that my duties, as vacation Judge at Kimberley, would debar me from attending, and that I feared the time was too short, and my leisure too scanty, to enable me to prepare anything in the nature of an address likely to prove either useful to the Conference or satisfactory to myself. However, on a reiterated request to do what I could, I have endeavoured to put together a few observations, and for their inadequacy and crudeness, of which I am fully conscious, I trust that the circumstances I have mentioned may to some extent be accepted as an excuse. I conceive that all interested in the subject of Public Libraries in South Africa must feel indebted to the Association for the opportunity afforded by this Conference of exchanging ideas, eliciting experience, and discussing some of the multifarious problems connected with the working, management, and development of the system of Public Libraries in this part of the world. A Scientific Association in its early days—as is shown for instance by the history of the Royal Society—can afford to be comprehensive in its ambit; as it matures, the success of its operations tends to specialise their nature and restrict its sphere. Possibly this section may not retain a permanent position in a scientific programme; if not, it may be hoped that, ere that day arrives, those interested in the subject may be able to maintain an association of their own.

## LIBRARY ASSOCIATIONS.

A good many years ago, as chairman of the Kimberley Library, I made some suggestions on the subject, and we decided to invite the co-operation of the South African Library at Cape Town; but the project at that time appeared to be premature, and I am not certain even now that we can expect its complete realisation in the immediate future. Library Associations have long existed both in England and the United States, and a similar society has recently been established—I know not with what measure of success—in the Australian

Colonies. Here in South Africa, while, under the system of local subscriptions, supplemented by Parliamentary grants, a good many small libraries have been established, and have exercised a beneficial influence within their sphere of operations, the number of institutions of a higher class, with anything like an adequate equipment, is extremely small, and the number of trained librarians is still smaller. There are not many other persons, bibliophiles or men of leisure with literary tastes, taking an active part in the administration of our libraries, who would be both able and willing to become working members of such a society and to attend those periodical conferences which are usually regarded as among its most useful and distinctive features. The great distances which in this country separate the principal centres of population form one of the most formidable barriers to such intercourse. It may, however, be suggested that something more might be attempted than has yet been done, with a view to bringing the various libraries and their representatives into closer contact with one another, to facilitate co-operation and diminish that feeling of isolation which under present conditions must often prove discouraging.

#### A LIBRARY JOURNAL.

One of the principal objects of such an association as I have mentioned would, I apprehend, be the establishment and maintenance of something in the nature of a library journal; and, while opportunities for personal conference must remain exceptional, much, I conceive, might be effected by the existence of such a vehicle of communication. The obstacles to such a step are no doubt considerable. That of ways and means is not, perhaps, the most serious. Such a journal, if published, say, at quarterly intervals, at a moderate price, and capably edited, would probably be subscribed for by almost every library in the country deserving of the name; it would afford a useful channel of publicity for advertisements of a certain type; and probably the committees of the principal libraries might be willing, as an experiment, to contribute a modest subsidy towards the expenses of its production. The difficulties of management and editing might prove more formidable. It would have to be issued from some permanent centre, with a local secretary, and possibly the burden of editorial supervision might be accepted in rotation—say for six months or a year—by some of the leading librarians, who would doubtless take a practical interest in such a project. Perhaps in the present paper it may not be wholly futile to make some attempt to indicate, without indulging in rhetoric or venturing on dogma, some few of the many topics for the discussion of which such a publication might afford an appropriate channel.

## OUR LIBRARY SYSTEM.

In the first place, with regard to the basis of the whole structure, it may be suggested that our present system of subscription libraries, though it has produced many useful results, is by no means an ideal one. It should be regarded rather as a wayside shelter than as a permanent abode. Under our present methods too much weight is almost inevitably given to the average opinion, and taste in current literature, of the average subscriber; too large a proportion of the available funds is frequently employed in the purchase of books of at best ephemeral interest and small literary merit; too little care and attention is devoted to the acquisition and building up of a comprehensive library of reference. Above all, so long as this system prevails, it is a misnomer to describe as "free," libraries which limit their circulation to those able and willing to pay for the privilege of borrowing books. I cannot help thinking that the question is well worthy of the consideration of municipal corporations; whether the time has not arrived at which such bodies might, under statutory powers which in some cases already exist, and in all cases might probably be obtained, properly apply some portion of their revenue, either by means of a special rate or by an appropriation from their general funds, to such educational purposes as the subsidising, on a substantial scale, of public schools and public libraries within their boundaries. From such libraries every ratepayer—possibly every resident recommended by a ratepayer—would be entitled, under reasonable restrictions, to borrow books, and it would still be feasible to augment our resources by means of subscriptions, giving the subscribers additional facilities, and conveniences of various kinds, such as they enjoy under the present system.

## COMMITTEES AND LIBRARIANS.

Such municipal support would imply a large measure of municipal control, and, as in England, the libraries might be managed by committees appointed by the borough councils, with a wide power of nomination outside their own body. Such committees, in my opinion, for effective work, should not be too large. Lord Palmerston used to say that the best number for a committee was three, and that the best results were attained when two of the three failed to attend. I will only submit that while the task of managing a public library affords infinite scope for criticism, usually most blatant when least informed, the best chance of success consists in selecting for such work those most competent to perform it, and in giving them, when appointed, a tolerably free hand. What I have said with regard to committees also applies to a great extent to librarians. The old idea that such a position should

be regarded as furnishing a suitable provision for some amiable individual with a taste for books, and a pronounced incapacity to earn his living in any other calling, may perhaps by now be regarded, even in this easy-going country, as at all events obsolescent. What we want in our librarians is a combination of wide literary knowledge, with practical training, businesslike habits, and a good deal of what has been described as flexibility of adaptation. "The librarian who reads is lost," is an often-quoted saying, which I fancy may be ascribed to one of the most learned academical students of the last century, Mr. Mark Pattison. It may be pointed out that the aphorism is ambiguous; it may not only imply, as it is commonly understood, that such an one is unfitted by his temperament for his avocation; it may also mean that the race of learned librarians—such persons for instance, as the late Mr. Bradshaw—is practically extinct and has been superseded by another type. I do not suggest that a librarian should be a sciolist, or that, as Macaulay declared of Brougham, he should "half know everything, from the cedar to the hyssop"; but it is perhaps desirable that he should neither, on the one hand, be too much of a specialist, nor, on the other, be wholly absorbed in the service of tables and matters of practical detail, such as types of indicators or improvements in the changing system. "I can't get my librarian," the chairman of an important institution once remarked, "to take any interest in 'incunabula'; his mind is engrossed by the question of umbrella stands." We must seek to strike the happy mean; all that can be suggested is that we must not demand too much, that librarians, like other folk, must be qualified to possess "the defects of their qualities," but that the successful progress of a library depends so much on its permanent staff that no effort should be spared to secure the services of thoroughly competent officials, who should be provided, having regard to local circumstances, in view of the position they occupy, and the responsible functions they are expected to discharge, with reasonable remuneration for their services. At the same time, while giving due recognition to the maxim that the labourer is worthy of his hire, we have to be constantly on our guard against any tendency to extravagance in our establishment charges, as well as in other departments of expenditure. Economy, I am well aware, in all the phases of public and private life, has long been sadly out of fashion; and we are beginning to appreciate some of the consequences of the mania for borrowing, and the general neglect, during the latter half of the last century, by Governments, by public bodies, corporations, and institutions, as well as by private individuals of Cicero's excellent maxim, "*magnum vectigal est parcimonia*"—(thrift is a great source

of income). The practice and advocacy of thrift is seldom popular; I can only urge that the matter is one requiring constant vigilance, and a good deal of moral courage. As it has been shrewdly affirmed that sound policy lies at the root of sound finance, so, without sound finance, and at least as careful supervision and discrimination in the expenditure of public funds as a prudent person would exercise with regard to his own income, depend upon it there can be no sound administration or satisfactory result. "We cultivate the liberal arts without extravagance," was the boast of Pericles in his analysis of the character of Athenians of his age; and when we remember that the age of Pericles was also the age of Pheidias, and the age of Sophocles, we may well be content to take their conduct in this respect as an example to emulate, and an ideal to pursue. Assuming then that our libraries are established on a sound basis, well officered and prudently administered, what are some of the salient problems to which our attention should be directed, and which, with special regard to South African circumstances, conditions, and requirements, may afford appropriate topics for ventilation in our future literary journal? I need scarcely repeat that I attempt no exhaustive category.

#### THE CHOICE OF BOOKS.

I will only mention, by way of illustration, four of the most important subjects, namely: (1) The choice of books; (2) binding; (3) classification; and (4) cataloguing. As to the choice of books, I do not approach the topic from the point of view of Mr. Frederic Harrison's essay, although his excellent advice to the individual reader (which may perhaps be summed up in the two words, "optimum elige"), should of course sedulously be borne in mind in the selection of works for a public library. Presuming, however, that you possess a good collection of what are conventionally described as the standard authors, both ancient and modern, British and foreign, in good, workmanlike editions (supplemented, in the case of the classics and foreign literature, by some judiciously selected translations), the question of the upkeep of your library presents innumerable problems of the greatest variety and interest. Such upkeep, if due discrimination be exercised, need not be too expensive. It has been asserted that a good general library can be maintained, and everything of real importance in current literature secured, at a cost of from £300 to £400 a year. I can only say that the more individual knowledge, care, and judgment brought to bear on the subject, the better the result will prove. According to my experience, a large proportion of the books required by a public library

can be best obtained by direct orders to some leading bookseller at Home, who makes a speciality of such work; on the other hand, it is scarcely satisfactory, except to a very limited extent, to leave the selection of books to the agent by whom they are supplied. We should always bear in mind that, of the annual output of books in all departments, probably not 5 per cent. will live for five years; and we should endeavour, not to charge either our revenue or our shelf accommodation, with a heavier burden of ephemeral matter than we can possibly avoid. Moreover, by no means all books, which may be worth acquiring, are worth buying at the high prices which it is still the fashion of the English trade in many cases—and particularly in the case of works of biography and travels—to charge on first publication. Such books can often be secured, by exercising a little patience, at a relatively low cost, either as second-hand copies, or as remainders, or in cheaper, but equally serviceable—sometimes, indeed, improved and revised editions. Many good bargains may also be obtained from the dealers' lists, and, though their perusal takes time, it is often well repaid, and, by practice, one can acquire the art of getting at the kernel without too much fumbling with the husk. It may also be a useful habit to keep a rough book in which to jot down notes of "desiderata" and "lacunae," and occasionally to send a list of such titles to some intelligent dealer, with a commission to supply as opportunity may serve. A useful test of the success which attends our efforts in this department may be made by working out, from time to time, the average cost of our accessions, as compared with the published price.

#### THE REFERENCE LIBRARY.

Another important matter is to determine approximately what proportion of outlay we are in a position to devote to our reference library, which of our accessions we should include in that branch, and under what conditions, if at all, we should allow such works to be taken out. It may perhaps be suggested that the reference library should itself be divided into two main classes or categories, one of which, embracing works of reference in the stricter sense, such as dictionaries and encyclopaedias, and works of special value or rarity, should never be allowed to leave the library premises, while others might be borrowed for limited periods, and under special restrictions and safeguards. I should like also to suggest that, among works of reference, much attention should be directed to the subject of bibliographies, both general and special, so that the student may be enabled to ascertain not only what the library actually possesses, but what it may be



expected to acquire, and what are the chief extant works dealing with the subject of his research. As to the reference library as a whole, it may perhaps be suggested that, of the funds available for the purchase of books, we ought to expend something like 30 per cent. on this department, which would probably represent something like 20 per cent. of the volumes purchased. Thus, if we spend £500 a year on acquiring 2,000 volumes, out of this sum about £150 would be devoted to the acquisition of about 400 volumes for this most important section. I may perhaps venture to add a general hint that in the choice of books we should ever bear in mind the character of our library, the local circumstances and conditions, and remember that a library, to be worthy of the name, must not be regarded as a mere collection or aggregation of so many thousand volumes, but as a living and growing organism, well proportioned in all its members, and with a healthy development in accordance with the functions they are expected to discharge. To assure such development, we should strive to enlist the co-operation of specialists in the various branches of our work, and, above all, to keep our minds, so to speak, steeped in a literary atmosphere, impregnated with all the phases of thought, and always on the alert to glean information, from every accessible source, which may aid us in the accomplishment of our important task. A good deal of help may often be obtained in the course of conversation with well-informed people on current topics, or from casual and incidental references in books or reviews, both English and foreign. I may perhaps venture to illustrate what I mean by mentioning that, not long ago, from the perusal of a novel by the late Mr. Gissing, called, I think, "Our Friend the Charlatan," I picked up a hint as to the subject and title of a French work—Izoulet's "Cité Moderne"—which proved a valuable accession to our library of political philosophy. A practice which I have myself found extremely useful is always to keep in one's pocket a little note-book, in which to jot down the titles and other particulars of works, the claim of which to be included in a future book order something read or heard may suggest to be worthy of subsequent consideration.

#### THE QUESTION OF BINDING.

With regard to the question of binding, I have merely to observe that this also is a subject on which the exchange of experience may prove highly advantageous, and to the discussion of which some space might well be devoted in our library journal. I had an interesting conversation on this question last year with Sir Edward Thompson, from whom I learnt that a committee of experts had recently been investi-



gating the matter at the British Museum, and had come to the conclusion that most of the materials used by the trade—whether described as calf, russia, or morocco—were so much adulterated by the use of various dyes and pigments that their durability was gravely impaired, and that radical changes in method were regarded as essential. I may also point out that the efficacy of binding is largely affected by climatic conditions, and that materials which may serve their purpose well enough in an English climate, or in that of our coast ports, may prove unsuitable to the drier atmosphere of Johannesburg or Kimberley, and vice versa. At all events until more information on this subject is available, my impression is that we should avoid the expense and delay entailed by re-binding as much as possible. Works of fiction will usually survive, for the brief life which is their portion, in their original boards, in which they can be supplied more rapidly, and, when necessary, a larger number of copies obtained than if time and money have to be expended on binding. Of other works, the circulation is seldom so extensive that the covers become worn out while they are still in demand; and by providing in our library a small workshop, with a few tools, for simple repairs, and replacing or re-binding individual works where necessary, a substantial saving in expenditure can probably on balance be effected. The covers supplied by the publishers are often disgracefully flimsy; so, for that matter, is the fastening of the sheets and the quality of the paper itself. All of these things may be included in the class of “perishables”; fortunately in many cases they deserve no better destiny; and their transitory life may afford an element of consolation to those who regard as one of the most serious dangers and perils by which our libraries are beset, the difficulty and expense—even if we utilise all the improvements of modern construction and appliances—of accommodating, or even warehousing, enormous modern accumulation of printed matter. Here, of course, there arises the thorny question of the elimination of the superfluous and the obsolete, as to which I will only say that it is an inviting topic, which might also furnish scope for an entire address, and to which considerations of time and space on the present occasion preclude more than a bare allusion.

#### CLASSIFICATION.

With regard to the classification of books, the question presents itself under two aspects—firstly, that of classification for cataloguing and bibliographical purposes; and, secondly, that of arrangement on the shelves. As to the former, I am inclined to think that the classification should not be too minute. At Kimberley we arrange our books in sixteen classes,

which on the whole has proved sufficient for practical purposes. You will always, in some form or other, require a "miscellaneous" class; but it is perhaps one of the best tests of good cataloguing if you succeed in keeping down that class to the most modest dimensions. The classes, of course, admit of much subdivision; for instance, in our library a book may be marked "R.L.G.N.," which would mean that it belongs to the reference class (R), that it is written in the French language (L), that its subject is scientific (G), and that the topics treated—probably gold or diamond mining—are mainly or largely South African (N). With regard to distribution of the shelves, our system has been to arrange the books in each class, both in the reference and the circulating library, as far as practicable in alphabetical order. This facilitates inspection and examination by readers, but involves some waste of space when books in the same class vary substantially in size. The tendency at the present day among librarians is, I understand, to favour the "Dewey," or decimal, or some other system of minute classification, the advantages of which must, I conceive, to some extent be counterbalanced by the highly diversified and miscellaneous character of the contents of many works, and the constant tendency to overlap from one subject to another. It is, moreover, I think, a useful practice to endeavour, as far as possible, to keep the works of the same author together, and occasionally to stretch a point in classification with that object in view.

#### OPEN ACCESS.

I have not time for more than a passing reference to the question, so hotly debated, of "open access" to the shelves. I can only say that the experience of all libraries, from the British Museum downwards, has proved the advantage of this system, so far at all events, as certain sections are concerned, and that the further it can be extended, without undue risk of confusion or loss, or serious addition to the cost of supervision, and the more such facilities can be afforded the more useful and popular our libraries are likely to prove.

#### CATALOGUING.

I come lastly to the great subject of cataloguing, as to which, on the present occasion, I can only add a very few words. The topic is one of which I am in a position to speak from practical experience. I myself devoted much of my leisure for some seven years to compiling a library catalogue and seeing it through the press, and for ten years more to making preparations and arranging materials for another edition, the completion of which I fear that, with impaired eyesight and diminished energy, I must now resign to other

hands. The work is one which involves infinite labour and minute examination and comparison with a view to the maintenance of uniformity of method and arrangement, especially so far as the subject index is concerned: while the utmost we can hope for is that the ultimate percentage of substantial errors, omissions, and inaccuracies, may not prove unduly high. The obvious objection to a printed catalogue is that, while its production implies enormous toil, it tends to become obsolete, even before it receives its "imprimatur." The advantage of possessing such an epitome of the contents of our library at a given date is, however, unquestionable: whether it is quite worth all the expense and effort involved to some measure depends on the extent to which the library is used by persons residing at some distance from the building. For libraries where the readers, with few exceptions, live in the immediate vicinity, a good system of card catalogues (both of authors and subjects) will serve most of our needs: and too much stress can hardly be laid upon the importance of all books being carefully catalogued, classed, and, when necessary, analysed, for this and analogous purposes, as soon as they are received. Much advantage may also be derived from the preparation, from time to time, of class lists and special bibliographies, and from the occasional collocation and exhibition in the library of such sections of its contents as relate to topics of current interest, or subjects likely, for one reason or another, to prove attractive to various classes of readers or students.

#### A SOUTH AFRICAN CATALOGUE.

There is one further suggestion, in connection with this subject, which perhaps I may venture to make. Has not the time arrived for a well-considered effort to produce as nearly as may be, an exhaustive catalogue of works relating to South Africa? An attempt in this direction was made some twenty years ago, by the late Mr. Fairbridge and Mr. Noble—both names of which the memory deserves to be cherished in this country by every lover of letters—in connection with the Colonial Exhibition of 1885: but it was very imperfect, and, in fact, practically confined to works contained either in the South African Library, or in the private collection of Mr. Fairbridge. Possibly, by way of a beginning, an effort might be made to prepare a catalogue of all works published during the first two centuries, namely, from Van Riebeeck's settlement to the year 1852, leaving the last half-century for a subsequent compilation. A list might be prepared and typed, taking that of Fairbridge and Noble as a basis, of the works contained in the South African Library and other collections at Cape Town. This might be circulated among the larger

and older libraries throughout South Africa, and inquiries made from others, and also from certain of the dealers, as to whether they possessed any books falling within that period, and thus, after consulting all accessible sources, something might be produced which would form a valuable contribution to Colonial bibliography. Such a catalogue should, I apprehend, contain information, which could be expressed by a few symbols and occasional footnotes, indicating where the books described could be seen, and every care should be taken that the descriptions should, as far as possible, be uniform in their character and in the particulars supplied. I would ask this Conference, before it disperses, to discuss the advisability of appointing committees to consider the feasibility of the two specific suggestions I have propounded, namely: (1) The establishment of a South African library journal; and (2) the compilation of a catalogue of all works published in, or relating to, South Africa, and issued prior to some definite date.

#### THE LIBRARY MOVEMENT: ITS AIMS AND OBJECTS.

My address has extended beyond the limits which I had contemplated, and, I fear, beyond what it was quite fair to inflict on your patience. I can only plead, as Pascal said, in terminating one of his Provincial Letters, that, had I had more time, I might have been able to make it shorter. May I say, in conclusion, that, although the library movement, like other movements, may be made the subject of extravagant eulogy, of ill-regulated enthusiasm, and of a zeal not always in accordance with knowledge, these are not the dangers and the risks to which in this country, and at the present day, we are most liable or prone. We have rather to contend with apathy and indifference, with an environment too much absorbed in the struggle for material well-being, and too much inclined to put off to a more convenient season the pursuit of the intellectual life. We may, however, feel assured that any time and labour we may devote to the work of improving our libraries and making them more and more centres of enlightenment, as well as means of culture and sources of mental recreation, will not be thrown away. With regard to book-lore, experience here, as elsewhere, shows that the supply always stimulates the demand; and there is no department of literature or science, however technical or esoteric—palæology, for instance, or palæontology—in which, if you supply the “pabulum,” and make provision for the needs of the student, the student will not by and by arrive. This is a country in which there is plenty of excellent raw material. The youth of South Africa have already in many instances acquired high distinction in some of the learned professions, and are likely in the future in

increasing numbers to take advantage of the opportunities for training now afforded in the applied sciences—in such branches, for instance, as civil, mechanical, and mining engineering. For all such wants and faculties and aptitudes our libraries should cater; they should become emporia of easily accessible information; they should enable every man and every woman, in their hours of leisure, to continue the education of which they acquired the rudiments in their youth; they should help to keep us, not only in touch with all the intellectual activities of the infant century in which we live, but also in spiritual communion with the great masters and thinkers of the past; and even amid the prosaic environment and work-a-day surroundings of our public libraries we should endeavour to cultivate something of the atmosphere of that Temple of Peace in which the illustrious statesman, whose life we have of late been reading, was wont to seek refreshment and repose, amid all his cares and toils and responsibilities, ever remembering, as he did, that, while the things which are seen are temporal, the things which are not seen are eternal.

REPORT OF THE SECOND ANNUAL MEETING OF THE ASSOCIATION,  
JOHANNESBURG, 1904.

The second annual meeting of the Association was held at Johannesburg, April 4th-9th, when the following programme was carried out:—

Monday, April 4th:—

4 p.m.—Meeting of Council.

8.30.—Opening meeting and President's address.

Conversazione held by the Chamber of Mines.

Tuesday, April 5th:—

9.30 a.m.—Meetings of Sectional Committees.

10 a.m.—Meetings of Sections.

8 p.m.—Popular lecture, "Road Locomotion," by Prof. Hele Shaw, F.R.S.

Wednesday, April 6th:—

9.30 a.m.—Meetings of Sectional Committees.

10 a.m.—Meetings of Sections.

3.30 p.m.—Drive round Johannesburg and suburbs by invitation of the Members of the Stock Exchange, the Chamber of Commerce, and the Chamber of Trade.

5.30 p.m.—Meeting of Council.

8.15 p.m.—Reception in the Wanderers' Hall by the Mayor and Town Council of Johannesburg.

Thursday, April 7th:—

8.30 a.m.—Excursion to Pretoria and to the Premier Diamond Mine.

Friday, April 8th:—

9.30 a.m.—Meetings of Sectional Committees.

10 a.m.—Meetings of Sections.

3 p.m.—Visits to the Robinson Deep, Ferreira Deep, and Robinson Mines.

6 p.m.—Inaugural meeting of the South African Ornithologists' Union.

8.30 p.m.—Reception by the Johannesburg Scientific Societies, on whose behalf Mr. R. M. Catlin received the members of the Association.

Saturday, April 9th:—

8.30 a.m.—Council meeting.

9 a.m.—Annual General Meeting.

10.45 a.m.—Excursion to the Dynamite Factory, Modderfontein, members being the guests of the South African Explosives Company.

At the Sectional meetings the following papers were read :

SECTION A.

April 5th :—

President's Address—The Metallurgy of the Witwatersrand, by J. R. Williams.

The Cyanide Process from the Standpoint of Modern Chemistry, by James Moir, D.Sc., M.A., F.C.S.

Reduction Works Checks, with special reference to early Practice on the Transvaal Gold Fields, by E. H. Johnson.

The Evolution in the Treatment of By-Products on the Witwatersrand Gold Fields, by M. Torrente.

April 6th :—

The Genesis of Soils, with special reference to the Transvaal, by A. F. Crosse.

The Chemical Industry of the Transvaal, a Forecast, by W. Cullen.

The Contact Process of Sulphuric Acid Manufacture, by E. Weiskopf.

Some Economic Problems in Metallurgy on the Witwatersrand, by H. S. Denny.

April 8th :—

The Blizzard of June 9th-12th, 1902, by C. M. Stewart, B.Sc.  
Results of some further Observations upon the Rate of Evaporation, by J. R. Sutton, M.A., F.R.Met.S.

SECTION B.

April 5th :—

President's Address—The History of Stratigraphical Investigation in South Africa, by Geo. S. Corstorphine.

The Geological Features of the Diamond Pipes of the Pretoria District, by H. Kynaston, M.A., and A. L. Hall.

Stone Implements from the farm Elandsfontein, No. 235, by J. P. Johnson.

The Witwatersrand Series—an Explanation of their Deposition, by A. von Dessauer.

Some Rare Metals found in the Transvaal—with special reference to Radium, by E. P. Rathbone.

April 6th :—

Alien Plants Spontaneous in the Transvaal, by J. Burt Davy.

Notes on the Vegetation of Southern Rhodesia, by R. Marloth, Ph.D., M.A.

Biological and Ethnological Observations on a Trip to the North-east Kalahari, by S. Schönland, Ph.D., M.A.

Additional Notes on the Development of South African Fishes, by J. D. F. Gilchrist, M.A., B.Sc., Ph.D.

Trout Acclimatisation, by B. Bennion.

April 8th :—

The Science of Bacteriology and its Commercial Value, by W. H. Jollyman.

A Further Note on the Co-relation of several South African Diseases of Stock, by Dr. A. Edington.

Rhodesian Tick Fever, by A. Theiler, M.D.

The Bacteriological Aspect of Miners' Phthisis, by L. G. Irvine, M.D., M.A.

Notes on some Pathogenic Bacteria as found in the Transvaal, and the Variations from their European Prototypes, by F. H. Joseph.

#### SECTION C.

April 5th :—

President's Address—Improvements in Rolling Stock, by Lieut.-Col. Sir Percy Girouard, K.C.M.G., D.S.O.

Diamond Drilling—Prospecting by Drills, by G. A. Denny.

Hydraulic Sluicing and Dredging for Gold, by J. H. Ronaldson.

Some Practical Observations on Forestry, by D. G. Muldoon.

Duration and Area of Heavy Rainfalls, by D. C. Leitch.

Some Considerations respecting Irrigation in the New Colonies, by W. Reid Bell.

April 6th :—

Survey Practice in the Transvaal, by P. B. Osborn.

The Mine Surveyor and his Work on the Witwatersrand, by A. E. Payne.

Geodetic Surveying, by W. H. Greathead.

Fire Protection on the Mines, by G. H. Thurston.

Use of Producer Gas-driven Engines on Mining Plants, by A. C. Whittome.

April 8th :—

The Bacterial Purification of Sewage, by E. S. Prentice.

The Septic Tank Treatment of Sewage, by J. C. I. Beynon.

Notes on Italian Architecture, by W. Leck.

Domestic Architecture, by E. W. Sloper.

Lightning Arresters for Electric Transmission Lines, by L. Wilms.



## SECTION D.

April 5th :—

Acting President's Address—The Education of Examiners, by E. B. Sargant, M.A.

The Prehistoric Monuments of Rhodesia, by F. P. Mennell.

Nature Study for South Africa, by W. L. Sclater, M.A.

April 6th :—

The Handling of Young Children, by P. A. Barnett, M.A.  
Special Assessments, by Stephen Court.

April 8th :—

Drawing for Young Children, by E. B. Sargant.

Inyanga Fort, by R. N. Hall.

A Plea for Native Education, by Basil Williams.

## ANNUAL GENERAL MEETING.

The annual general meeting of the Association was held on Saturday, 9th April, at 10 a.m., in the rooms of the Transvaal Technical Institute, Von Brandis Square, Sir Charles Metcalfe, President, in the chair.

It was unanimously decided that the thanks of the Association be tendered :—

To His Excellency Lord Milner, G.C.B., G.C.M.G.

To His Excellency Sir Arthur Lawley and Lady Lawley.

To the Mayor and Corporation of Johannesburg.

To Sir George and Lady Farrar.

To Mr. and Mrs. T. Reunert.

To the Director of Education, the Technical Institute, and the Educational Advisor to the Transvaal and Orange River Colony, for accommodation provided.

To The Witwatersrand Council of Education, for financial assistance.

To The Stock Exchange.

To The Transvaal Chamber of Mines.

To The Chamber of Commerce

To The Chamber of Trade.

To The Commissioner of Police.

To The Committees of the Rand Club, The New Club, and The Athenaeum Club, Johannesburg, and The Pretoria Club and The New Club, Pretoria.

To the following Scientific Societies :—

South African Association of Engineers.

Chemical, Metallurgical and Mining Society of S.A.

Mechanical Engineers' Association of the Witwatersrand.  
Association of Mine Managers (Witwatersrand).

Geological Society of South Africa.

Transvaal Philosophical Society.

The Society of Accountants and Auditors. (Trans. Branch).

Institute of Land Surveyors, Transvaal.

Transvaal Medical Society.

The Incorporated Law Society of the Transvaal.

Institute of Mine Surveyors (Transvaal).

Transvaal Association of Architects.

Field Naturalists' Club.

To The Management of the Premier Diamond Mine, coupled with the names of Messrs. Cullinan and Tracey.

To The Management of the Robinson, Robinson Deep, Ferreira, and Ferreira Deep G.M. Companies.

To The Management of the S.A. Explosives Co., Modderfontein, including Mr. W. Cullen.

To The various Railway Administrations of South Africa for railway facilities granted.

To The Union-Castle S.S. Co. for travelling facilities granted.

To The Public Library.

To The Press, for the excellent manner in which they have reported this Meeting.

To all those who contributed specimens and exhibits to the Museum.

To the authors of papers in the Official Programme, and to Mr. Frank Flowers for providing maps and plans.

To all who have in any way assisted in the arrangements for the Meeting.

The following office-bearers and members of Council for 1904-1905 were elected.

*President :*

THEODORE REUNERT, M.I.C.E., M.I.M.E.

*Vice-Presidents :*

JAMES FLETCHER, Durban.

SIDNEY J. JENNINGS, M.Amer.I.M.E., M.I.M.E., Johannesburg.

DR. T. MUIR, C.M.G., LL.D., M.A., F.R.SS., L. & E., Cape Town.

GARDNER F. WILLIAMS, Kimberley.

*Members of Council :*

*Bloemfontein.*

JAMES LYLE.

*Bulawayo.*

FRANKLIN WHITE.

*Cape Town.*

PROF. J. C. BEATTIE.

PROF. L. CRAWFORD.

PROF. P. D. HAHN.

DR. R. MARLOTH.

*Cape Town.—(Contd.).*

ARTHUR H. REID.

W. L. SCLATER.

ALBERT WALSH.

*East London.*

JOHN WOOD.

*Graham's Town.*

DR. A. EDINGTON.

DR. S. SCHONLAND.

*Johannesburg.*

DR. G. S. CORSTORPHINE.  
 SIR PERCY FITZPATRICK.  
 R. T. A. INNES.  
 PROF. J. G. LAWN.  
 J. R. WILLIAMS.  
 DR. W. C. C. PAKES.  
 PROF. ORR.  
 W. A. CALDECOTT.  
 E. J. LASCHINGER.  
 DAVID GILMOUR.  
 ERNEST WILLIAMS.  
 SIR GEORGE FARRAR.  
 HOWARD PIM.  
 FRANK FLOWERS.  
 G. S. BURT ANDREWS.  
 A. VON DESSAUER.  
 DR. F. H. HATCH.

*Kimberley.*

D. W. GREATBATCH.  
 THOMAS QUENTRALL.

*King William's Town.*

DR. H. M. CHUTE.

*Komati Poort.*

W. HUTTON.

*Lovedale.*

DR. ALEXANDER W. ROBERTS.

*Pietermaritzburg.*

J. W. SHORES.  
 P. A. BARNETT.

*Port Elizabeth.*

THOS. REEVE,

*Pretoria.*

J. BURTT DAVY.  
 H. KYNASTON.  
 F. B. SMITH.

*Queenstown.*

E. E. GALPIN.

*Salisbury.*

GUY A. K. MARSHALL.

*Simon's Town.*

D. MACFARLANE.

*Stellenbosch.*

PROF. J. T. MORRISON.

*Ex-Officio.*

Hon. Secretaries: DR. J. D. F. GILCHRIST. WILLIAM CULLEN.

Hon. Treasurer: W. WESTHOFEN, P.W.D., Cape Town.

Past Presidents: SIR DAVID GILL, H.M. Astronomer at the Cape.  
 SIR CHARLES METCALFE, BART., M.I.M.E., Cape Town.

*Assistant General Secretaries:*

Cape Colony and Rhodesia: E. H. JONES, P.O.Box 1497, Cape Town.

Transvaal, Natal, and Orange River Colony: E. M. AINGE, P.O. Box 6674,  
 Johannesburg.

# REPORT OF THE COUNCIL FOR THE PERIOD FROM 3RD MAY, 1903, TO 9TH APRIL, 1904.

1. Since the last report of the Council the Association has made considerable progress. The membership has greatly increased during the past year, and on the closing day of this, the Second Annual Session, the number, including 160 Associate Members, is 1,073, showing an increase of 326.

2. The Report of the Treasurer, with Financial Statement for the year ending 30th June, 1904, is printed in this Report.

3. The Council regrets that such large sums are outstanding for subscriptions, and unless these are paid within a reasonable time it will be necessary to consider the advisability of removing from the Register the names of those members who are in arrear.

4. The Report of the First Annual Meeting, held in Cape Town from the 27th April to 2nd May, 1903, was published on

the 26th February last, and a copy has been sent to every member whose subscription has been paid up to the 30th June, 1903.

5. The Report is published by the Association, and copies may be had on application to either of the Secretaries, or to Messrs. J. C. Juta and Co., Booksellers, Cape Town. The price of the Association's Report has been fixed at One Pound, but members of the Association may obtain the same for Ten Shillings, on application to either of the Secretaries.

A list of the Societies, Public Institutions, etc., to which a copy of the Report has been presented will be found on page 586.

6. The Council joined other scientific bodies in South Africa in inviting the Triennial International Geological Congress to visit South Africa in the year 1906. The invitation, however, has not been accepted, as the Congress has decided to visit Mexico.

7. In response to requests the Council has added Metallurgy to the list of subjects in Section A, and Forestry to Section C.

8. Grants in Aid of Research Work.—On the 7th August last applications were invited from members for Grants in Aid of Research Work. The applications were to be received by the Secretary not later than 31st December, 1903, and to be finally dealt with by the Council at the Second Annual Session.

As a result of this invitation the following applications were received:—

By Professor H. H. W. Pearson, M.A., F.L.S., South African College, for the sum of Twenty-five Pounds in aid of research on *Welwitschia mirabilis*.

By Mr. J. Burt Davy, F.L.S., F.R.G.S., Government Botanist, Pretoria, for the sum of Fifty Pounds to aid in the preparation of an Annotated Catalogue of the Flowering Plants and Ferns known to occur in the Transvaal.

By Mr. R. T. A. Innes, F.R.A.S., Meteorological Observatory, Johannesburg, for the sum of Twenty-five Pounds, in aid of the work of preparing Tables of the Barometric Pressures over South Africa and adjacent regions.

A committee, consisting of Dr. Harry Bolus, Dr. R. Marloth, and Dr. S. Schonland, was appointed by the Council to consider and report on the applications by Professor Pearson and Mr. Burt-Davy; and Mr. Innes' application was referred to a committee consisting of Sir David Gill and Dr. T. Muir.

At a meeting of the Council, held during the Second Annual Session, the payment of the grants in terms of the recommendations of the Committees was unanimously authorised.

9. The Council received invitations from Kimberley and Durban for the meeting of the Association in 1906. These invitations were referred for consideration by the Council during the Second Annual Session at Johannesburg, and at a meeting held there on the 4th April it was decided to accept the Kimberley invitation, as it was received first.

10. At the request of the Johannesburg Local Committee, Sir David Gill re-delivered his Presidential Address in the Johannesburg Public Library, on Thursday, 14th May, 1903.

11. On the 16th November, 1903, the Johannesburg Committee elected a permanent Astronomical Committee, consisting of Messrs. Playford, Reunert, and Dumat, and it is hoped that their labours may result in the establishment of a small Observatory.

12. During the year considerable progress was made with the establishment of the Meteorological Station, which is expected to be in full working order by the end of May. The Director, Mr. R. T. A. Innes, has in the meantime been employed collecting data and establishing recording stations throughout the country. The benefits resulting from the establishment of this most important department should soon be felt.

13. The second Annual Session of the Association was held in Johannesburg.

14. The Sectional Committees, with their Presidents and Secretaries, were elected at a meeting of the Local Committee on 14th September, 1903. At a subsequent meeting it was decided to have a temporary loan collection on exhibition during the session.

15. Reception, Entertainment, Business, and Press Committees were elected towards the end of the year.

16. A Reception Committee was also formed in Pretoria, and was responsible for all the arrangements on the occasion of the Association's visit there.

17. Shortly before the Session it was reported that plague had broken out in Johannesburg, and it was thought that this would militate against the success of the meeting, but this happily did not prove the case.

18. On account of illness Sir Percy Fitzpatrick was prevented from taking part in the proceedings.

19. The Session opened on Monday, April 4th, and continued during the week, closing on Saturday, the 9th April.

20. His Excellency the High Commissioner, Lord Milner, presided at the opening meeting, at which Sir Charles Metcalfe delivered his Presidential Address.

21. The sectional meetings were held on the premises of the Technical Institute, Von Brandis Square, and the Com-

mittee and Council meetings in the rooms of the Education Department, both places being kindly lent for the occasion.

22. Under the auspices of the Association the first conference of librarians and those interested in the libraries of South Africa was held on Tuesday, the 5th April. Mr. Reunert presided over the conference, and Mr. Bertram L. Dyer gave particulars regarding all the South African libraries. Mr. Justice Laurence was unable to be present, but his inaugural address was read. At the end of the proceedings it was unanimously agreed to ask the Council of the Association to arrange a special sub-section of Section D at all future annual meetings to deal with the question of libraries.

23. The attendance at the various sectional meetings was very good, evidencing on the part of the public an increased interest in the work of the Association.

24. The proceedings were rendered more than usually interesting by visits to the mines, Pretoria, and the Dynamite Factory. The temporary loan collection proved of great interest, and was visited by a large number of the general public.

25. On the opening day of the Meeting the following cable was received from the British Association:—"British Association wish meeting success. Hope theirs same 1905"; to which the following reply was sent:—"South African Association of Science thank you for your kind message, and look forward with confidence and best wishes to your meeting here next year."

26. In view of the visit of the British Association to South Africa next year the Third Annual Meeting of this Association will be merged in that of the British Association. The Meeting will open at Cape Town in August.

W. CULLEN,  
J. D. F. GILCHRIST,  
*Hon. Secretaries.*

REPORT BY THE HON. TREASURER FOR THE YEAR ENDED 30TH  
JUNE, 1904.

Although desired by the Council, it has not been practicable to prepare a single financial statement dealing with the whole of the funds of the Association, and two separate statements are therefore again submitted.

The membership of the Association has largely increased during the year, but on the other hand a considerable number of original or foundation members have failed to pay the whole or part of their subscriptions due, and it will be necessary to remove some 60 names from the list.

The Hon. Treasurer regrets to have again to draw attention to the fact that members fail—in spite of repeated reminders—to fulfil their obligations in respect to payment of subscriptions, and there is at the present moment—independent of those alluded to above—a sum of nearly £500 outstanding. In this total are included the subscriptions for the current year, which became due on the 1st July last.

This neglect on the part of so many members of the Association interferes with its usefulness to a serious degree, inasmuch as the amount available for grants in aid of original research have to be limited in accordance with funds in hand.

It had the further effect of preventing the Council from investing in the names of trustees the life subscriptions and entrance fees in compliance with sub-section C. of Section 11 of the Constitution.

W. WESTHOFEN,

*Hon. Treasurer.*

# SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

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## STATEMENT OF INCOME AND EXPENDITURE FOR THE 3 YEARS ENDED 30TH JUNE, 1904.

INCOME.		EXPENDITURE.	
To Entrance Fees	... £46 0 0	By Salaries	... £303 8 8
„ Subscriptions :—		„ Printing and Advertising	... 131 5 5
On account of Johannesburg	20 10 0	„ Travelling Expenses	... 22 0 0
Associates	32 5 0	Audit Fees	... 10 10 0
Life Members	70 0 0	Sundry Expenses	... 106 1 2
Year 1901-2	171 10 0		£573 5 3
„ 1902-3	307 0 0	„ Grants	... 50 0 0
„ 1903-4	237 0 0	„ Refund of Johannesburg Subscriptions	100 0 0
„ 1904-5	6 0 0	„ Standard Bank—Balance	234 9 7
	890 5 0	„ Treasurer—Cash on hand	35 12 2
„ From Johannesburg	100 0 0		270 1 9
„ Reports sold	2 0 0		
„ Tram Fares recovered	1 2 0		
	£993 7 0		£993 7 0

I certify that the foregoing Statement has been made up from the Treasurer's Books, with which it agrees.

J. M. P. MUIRHEAD, F.S.A.A., F.C.I.S., Etc.,  
Auditor.

REPORT—1904.



# SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

## (JOHANNESBURG BRANCH.)

BALANCE SHEET FOR YEAR ENDING 30TH JUNE, 1904.

BALANCE SHEET.							
To Cash in hand 1st July, 1903...	£11	7	2	By Stamps and Telegrams	£29	13	0
„ Remittance from Treasurer, Cape Town, towards expenses of 1904 Meeting ...	100	0	0	„ Stationery	4	1	0
„ Subscriptions :—				„ Printing	32	10	6
403 Members at £1	£403	0	0	„ Meeting, 1903	10	1	0
135 Associate Members at 15s.	101	5	0	„ „ 1904	141	1	2
Arrears ...	13	14	0	„ Incidentals	3	10	1
	—	517	19	„ Salaries	184	16	5
„ Two Life Members' Subscriptions	20	0	0	„ Carriage from Cape Town on 90 copies of 1903 Report	3	5	9
„ Entrance Fees	144	0	0	„ Cash in hand on 30th June, 1904	785	17	3
	—	164	0				
„ Govt. Grant for printing 1904 Report...	400	0	0				
„ Sale of Three copies of 1903 Report ...	1	10	0				
	£1,194	16	2				

Examined and found correct. (Sgd.) HOWARD PIM, C.A., Hon. Auditor.

# CONSTITUTION OF THE ASSOCIATION.

## I.—OBJECTS.

The objects of the Association are:—To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of Societies and individuals interested in Science in different parts of South Africa; to obtain a more general attention to the objects of pure and applied Science, and the removal of any disadvantages of a public kind which may impede its progress.

## II.—MEMBERSHIP.

(a) All persons interested in the objects of the Association are eligible for Membership.

(b) The Association shall consist of Permanent Members, hereafter called "Members," and Temporary Members, hereafter called "Associates."

(c) Members shall be elected directly by the Council; Associates by Local Committees.

(d) The Council shall have the power, by a three-fourths vote, to remove the name of anyone whose Membership is no longer desirable in the interests of the Association.

## III.—PRIVILEGES OF MEMBERS AND ASSOCIATES.

(a) Members shall be eligible for all offices of the Association, and to serve on its Committees, and shall be entitled to a copy of all ordinary publications issued by the Association subsequent to the date of their election.

(b) Associates are eligible to serve on the Local Reception Committee, but are not eligible to hold any other office, and they are not entitled to receive gratuitously the publications of the Association.

## IV.—SUBSCRIPTIONS.

(a) The Annual Subscriptions for Members shall be One Pound, payable first at election, and thereafter on the First of July of each year. After the first session intending Members shall be required to pay an Entrance Fee of One Pound, in addition.

(b) A Member may at any time become a Life Member by one payment of Ten Pounds, in lieu of future Annual Subscriptions, or in lieu of Entrance Fee and future Annual Subscriptions.

(c) The Annual Subscription for Associates shall be Fifteen Shillings.

(d) The Council may authorise Local Committees to admit students as Associates at a reduced subscription on the special circumstances of each case being submitted.

## V.—MEETINGS.

The Association shall meet in Session periodically for one week or longer. The place of meeting shall be appointed by the Council as far in advance as possible, and the arrangements

for it shall be entrusted to the Local Committee, in conjunction with the Council.

#### VI.—COUNCIL.

(a) The Management of the affairs of the Association shall be entrusted to a Council.

(b) The Council shall, in the first instance, be elected by the General Committee, and shall consist of Twenty-five Members. Thereafter it shall consist of the President and four Vice-Presidents of the Association, Past Presidents of the Association, Past and Present General Secretaries and Treasurers, representatives to be elected by each Centre in the proportion of one representative for every 25 Members, and such others to be elected by the Members at the Annual Meeting of the Association, as shall give altogether one Member of Council to every 25 Members of the Association.

(c) The Council so elected shall at once proceed to elect the President, Vice-Presidents, two Secretaries, Treasurer, and an Assistant General Secretary. The Council shall have the power to pay for the services of the Assistant General Secretary, and for other such clerical assistance as it may consider necessary.

(d) During any Session of the Association the Council shall meet, at least, twice.

(e) The Council shall have the power to frame Bye-laws to facilitate the practical working of the Association, so long as these Bye-laws are not at variance with the Constitution.

#### VII.—MANAGING COMMITTEE OF COUNCIL.

In the intervals between the Sessions of the Association, its general affairs shall be managed by a Committee of Council, consisting of President, General Treasurer, General Secretaries, and four other Members, elected annually by the Council.

#### VIII.—LOCAL COMMITTEES.

In the intervals between the Sessions of the Association, its local affairs shall be managed by the Local Committees. This Committee shall consist of the Members of the Council resident in that Centre, with such other Members of the Association as the said Members of Council may elect.

#### IX.—RECEPTION COMMITTEE.

The Local Committee of the Centre at which the Session is to be held shall form a Reception Committee, to assist in making arrangements for the meeting, and for the reception and entertainment of the visitors. This Committee shall have power to add to its number from among the Members and Associates of the Association.\*

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\* For arrangements with regard to Papers to be read, see Section XIV.

## X.—HEADQUARTERS.

The Headquarters of the Association shall be in Cape Town at the outset.

## XI.—FINANCE.

(a) The Financial Year shall end on the 30th of June.

(b) All sums received for Life Subscriptions and for Entrance Fees shall be invested in the names of three Trustees appointed by the Council, and only the interest arising from such Investment shall be applied to the uses of the Association.

(c) Subscriptions shall be collected by the Local Secretary of each Centre, and by him forwarded to the General Treasurer.

(d) The Local Committees shall not have power to expend money without the authority of the Council, with the exception of the Local Committee of the Centre at which the next ensuing Session is to be held, which shall have the power to expend money collected, or otherwise obtained in that Centre. Such disbursements shall be audited, and the balance-sheet and the surplus funds forwarded to the General Treasurer a month before the end of the Financial Year.

(e) All Cheques shall be signed either by the General Treasurer and a General Secretary, or by the Local Treasurer and Secretary of the Centre at which the next ensuing Session is to be held.

(f) Whenever the balance in the hands of the Treasurer shall exceed the sum requisite for the probable or current expenses of the Association, the Council shall invest the excess in the names of the Trustees.

(g) The whole of the accounts of the Association, *i.e.*, the local as well as the general accounts, shall be audited annually by an auditor appointed by the Council, and the Balance-sheet shall be submitted to the Council at the first meeting thereafter, and be printed in the Annual Report of the Association.

## XII.—GRANTS FOR RESEARCH.

(a) Grants may be made by the Association to Committees or to individuals for the promotion of Scientific Research.

(b) Committees and individuals to whom grants of money shall be entrusted are required to present to the following Meeting a report of the progress which has been made, together with a statement of the sums which have been expended. Any balance shall be returned to the General Treasurer. In each Committee the Secretary is the only person entitled to call on the Treasurer for such portions of the sums granted as may from time to time be required. In making grants of money to Committees or to individuals, the Association does not contemplate the payments of personal expenses to the Members, or to individuals.

## XIII.—SECTIONS OF THE ASSOCIATION.

The Council shall have the power to constitute such sections of the Association as it may consider necessary, the following being constituted at the outset:—

- A. Astronomy.  
Chemistry.  
Mathematics.  
Meteorology.  
Physics.
- B. Anthropology and Ethnology.  
Bacteriology.  
Botany.  
Geography.  
Geology and Mineralogy.  
Zoology.
- C. Agriculture.  
Architecture.  
Engineering.  
Geodesy and Surveying.  
Sanitary Science.
- D. Archæology.  
Education.  
Mental Science.  
Philology.  
Political Economy.  
Sociology.  
Statistics.

## XIV.—SECTIONAL COMMITTEES.

(a) The Presidents, Vice-Presidents, and Secretaries of the several sections shall be chosen by the Council, after consultation with the Local Committee of the Centre at which the next ensuing Session of the Association is to be held.

(b) From the time of their election, which shall take place as soon as possible after the Session of the Association, they shall form themselves into an organising Committee for the purpose of obtaining information upon Papers likely to be submitted to the Sections, and for the general furtherance of the work of the Sectional Committees. The Sectional Presidents of former years shall be *ex officio* members of the Organising Committee.

(c) The Sectional Committee shall have power to add to its number from among the Members and Associates of the Association.

(d) The Committees of the several Sections shall determine the acceptance of Papers before the beginning of the Session, keeping the General Secretaries informed from time to time of their work. It is therefore desirable, in order to give an opportunity to the Committees of doing justice to the several communications, that each author should prepare an abstract of his

Paper of a length suitable for insertion in the published Transactions of the Association, and he should send it together with the original Paper, to the Secretary of the Section before which it is to be read, so that it may reach him, at least, a fortnight before the Session.

(*c*) Members may communicate to the Sections the Papers of non-members.

(*f*) The Author of any Paper is at liberty to reserve his right of property therein.

(*g*) The Sectional Committees shall meet not later than the first day of the Session in the Rooms of their respective Sections, and prepare the programme for their Sections and forward the same to the General Secretaries for publication.

(*h*) The Council cannot guarantee the insertion of any Report, Paper, or Abstract in the the Annual Volume unless it be handed to the Secretary before the conclusion of the Session.

(*i*) The Sectional Committees shall report to the Council what Reports, Papers, or Abstracts it is thought advisable to print, but the final decision shall rest with the Council.

#### XV.—RESEARCH COMMITTEES.

(*a*) In recommending the appointment of Research Committees, all Members of such Committees shall be named, and one of them, who has notified his willingness to accept the office, shall be appointed to act as Secretary. The number of Members appointed to serve on a Research Committee shall be as small as is consistent with its efficient working. Individuals may be recommended to make reports.

(*b*) All recommendations adopted by Sectional Committees shall be forwarded without delay to the Council for consideration and decision.

#### XVI.—ALTERATION OF RULES.

Any proposed alteration of the Rules

(*a*) Shall be intimated to the Council Six Months before the next Session of the Association,

(*b*) Shall be duly considered by the Council,

(*c*) And, if approved, shall be communicated by Circular to the Members of Association for their consideration,

(*d*) And dealt with at the said Session of the Association.

#### XVII.—VOTING.

In Voting for Members of Council, or on questions connected with Alteration to Rules, absent Members may record their vote in writing.

LIST OF MEMBERS OF THE SOUTH AFRICAN ASSOCIATION FOR THE  
ADVANCEMENT OF SCIENCE, AT JUNE 30TH, 1904.

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° Indicates Life Members.

\* Indicates Foundation Members, i.e., those who were members of the  
Association on June 30th, 1902.

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*Members are requested to notify the Secretary of any corrections that may be  
needed in the list.*

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- ° Ababrelton, Robert, F.R.C.I., F.R.E.S., P.O. Box 322, Pietermaritzburg, Natal.
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